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SOIL AND GROUND WATER INVESTIGATION

COAL TAR DISTILLATION & WOOD PRESERVING SITE
ST. LOUIS PARK, MINNESOTA

PHASE I REPORT

MAY 1976

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CONSULTING ENGINEERS
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PHASE I REPORT

SOIL AND GROUND WATER INVESTIGATION

COAL-TAR AND WOOD PRESERVING SITE

ST. LOUIS PARK

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COAL-TAR DISTILLATION AND WOOD PRESERVING FACILITY

ST. LOUIS PARK

SUMMARY

The purpose of this report is to summarize the first phase of a study to evaluate the impact of the former coal-tar distillation and wood preserving facility in St. Louis Park on the soil and ground water systems in the area. The general objectives of the overall study are to:

a. measure the extent of coal-tar derived wastes in the glacial soils,

b. measure the effect of these wastes on the ground water systems,

c. define the interactions between the various ground water systems,

d. predict future impacts of the waste deposits on the ground water systems and

e. recommend corrective actions and future studies necessary to solve identified problems.

The work scope of the overall study was divided into two phases so the data collected during the early phase could be reviewed and the work scope adjusted, if necessary, to effectively meet the study objectives. The purpose of this Phase I report is to summarize and interpret the data collected during Phase I of the study. After the data collected during Phase I has been reviewed, the additional data collection activities necessary to attain the first three objectives of the study will be defined and carried out. Concurrently, the effect of the wastes on the surficial and bedrock ground water systems will be predicted and techniques to mitigate the impact of the wastes will be evaluated.

Fourteen soil borings were placed during Phase I to collect soil samples for chemical analyses and to define the characteristics of the glacial soils. Borings were placed in the northern one-half of the site, in areas on the southern portion of the site suspected of being saturated with coal-tar derivatives during facility operation, and south of the site in drainageways and catchment areas for wastes that left the site. Soil samples were typically collected at 5 foot intervals throughout the soil column and, where visible coal-tar wastes were present, samples were often collected at 2-1/2 foot intervals. The requirements of the soil sampling program and the nature of the soils in the study area required that care be taken to insure that a representative soil sample was collected.

Soil samples collected from the fourteen borings were visually classified and were used to obtain a general idea of glacial soil characteristics overlying bedrock in the study area. Glacial soils in the area are characterized by glacial outwash and ice contact deposits ranging from fine sands to coarse gravels. These outwash and ice contact deposits are separated by strata of glacial till ranging from fine silty sands to a sandy clay. The glacial till strata occurred at different elevations in the soil borings and interpreting the location of the till strata between borings is difficult. The till was found to be thin in places and it is possible that the till strata are missing in some areas. It is also possible that some till strata were missed due to the sample collection spacing of 5 feet.

The chemical analyses of soil samples included measuring the phenolic material and benzene extractable material in all soil samples as a gross indicator of the relative amount of the coal-tar derived wastes present in the samples. The phenolic and benzene extractable concentrations in the soil samples for each boring were utilized to draw contours of equal benzene extractable concentrations and equal phenolic concentrations on various geologic sections drawn through the study area. In general, the data indicates low but still detectable levels of phenolic and benzene extractable material in the soil samples collected on the northern portion of the site. Highest concentrations of benzene extractable and phenolic materials were found off the site between Walker Street and Lake Street with either low or undetectable levels of phenolic material and benzene extractable material found in samples from the single boring placed south of Lake Street. The concentration contours indicate a generally increasing concentration of both phenolic and benzene extractable material with increasing depth in the glacial soils in a southerly and southeasterly direction from the site.

In addition to the analyses of phenolic and benzene extractable materials, eleven soil samples were analyzed using thin layer chromatography techniques to determine the presence or absence of polynuclear organic materials in the samples. Gas chromatography techniques were then carried out on five of the samples to define the concentrations of the various polynuclear organic materials that were present. The objective of the thin layer chromatography/ gas chromatography analysis was to begin defining the extent to which the polynuclear organic materials are moving from the coal-tar wastes identified in the various soil borings. The data indicated that polynuclear organic materials were present in all eleven soil samples with significantly high concentrations present in sand samples collected from depths of 32 feet and 50 feet between T.H. 7 and Lake Street. Greater quantities of polynuclear organics, benz(c)phenanthrene, chrysene and benz(a)pyrene were found in the sand strata than in the underlying till strata between T.H. 7 and Lake Street. The quantification of polynuclear organic material at depths of 32 and 50 feet in the soil columns south of the site is one of the significant findings of the Phase I study. The data indicates that the polynuclear organic materials are concentrated above the till strata and that the polynuclear organic materials have moved below the upper till stratum in the glacial soils south of the site.

A total of nine ground water monitoring wells were installed during the Phase I study. Ground water samples were collected from these monitoring wells, from three St. Louis Park City Wells northeast of the site and from two industrial wells south and southeast of the site. The water samples indicated that detectable phenolics and benzene extractable materials were present in wells located on the site's south boundary and in wells located southeast of the site. No detectable phenolics were found in the City wells, in a bedrock well located northeast of the site, in an industrial well located south of the site or in glacial drift monitoring wells located north, west and east of the site.

The Phase I study of aquifer interactions revealed that the soils in the study area exhibit a wide range of water-transmitting capabilities. The two pumping tests carried out on the City well field located north of the site indicated that the leakage through the confining bedrock aquifer separating the glacial soils from the upper sandstone aquifer (St. Peter) was not measurable and that the vertical permeability of the bedrock units between the upper sandstone aquifer (St. Peter) and the second sandstone aquifer (Jordan) was on the order of 10^{-6} cm/sec. The data from the two pumping tests was limited since the pumping test had to be of short duration, since data was collected in the area of the pump test may not be representative of conditions in other portions of the study area and due to the somewhat unknown nature of the well characteristics.

INTRODUCTION

In November, 1975, Barr Engineering Co. was retained by the Minnesota Pollution Control Agency to evaluate the impact of the former coal-tar distillation and wood preserving facility in St. Louis Park on the soil and ground water systems in the area. Specifically, the objectives of the study are to:

a. measure the extent of coal-tar derived wastes in the glacial soils,
b. measure the effect of these wastes on surficial and bedrock ground water systems,
c. define the interactions between the surficial ground water system and the underlying bedrock aquifers,
d. predict future impacts of the waste deposits on the ground water systems,
e. recommend corrective actions and future studies necessary to solve identified problems.

The scope of the study was divided into two phases so that the data collected during the early phase could be reviewed and the work scope adjusted, if necessary, to effectively meet the study objectives. Phase I of the study was, therefore, designed to begin defining the vertical and horizontal extent of coal-tar wastes in the soils overlying bedrock, the general quality of the glacial drift ground water system and the interactions between the glacial drift ground water aquifers and the bedrock aquifers. The emphasis of the Phase I soil and ground water data collection program was placed on utilizing general indicator parameters to broadly define the location and extent of coal-tar wastes in the soil and ground water systems and on carrying out a limited number of more detailed analyses to begin defining how the various compounds known to be in the wastes are migrating vertically and laterally.

The following data collection techniques were used to collect the information for Phase I of the study:

a. Soil Borings. A total of fourteen soil borings were used to collect soil samples for chemical analysis and to better define the stratigraphy of the glacial soils in the study area.* Representative subsamples of all soil samples collected from the fourteen Phase I soil borings were analyzed for phenolic material and for benzene extractable material to broadly indicate the presence of coal-tar derived wastes. In addition, eleven selected soil samples were analyzed by thin layer chromatography techniques to qualitatively define the presence of polynuclear organic materials. Five of these samples were also analyzed by gas chromatography techniques to quantitatively measure the concentration of six polynuclear organics. The soil samples were visually classified to define the stratigraphy of the soils in the area. The grain-size distributions of typical soil samples collected from the Phase I soil borings were used to estimate the permeabilities of the aquifers and confining layers in the glacial soils.

b. Ground Water Quality Monitoring Wells. A total of nine ground water monitoring wells were placed in the glacial soils and shallow bedrock in the study area during Phase I. Ground water samples were collected from the monitoring wells and from municipal and industrial bedrock wells in the study area. The ground water samples were analyzed for a

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*For the soil investigation portion of the study, the term "study area" refers to the area within the boundaries of the former coal-tar and wood preserving facility (referred to as the site) plus areas south of the site that received runoff from the site. For the ground water investigation portion of the study, the term "study area" refers to a larger area including the municipal wells located at the City of St. Louis Park's well field at 29th Street and Idaho Avenue.

number of indicator parameters including phenolics, benzene extractable material, total dissolved solids and specific conductance.

c. Aquifer Pumping Tests. The vertical leakage between the lower glacial drift aquifer and the St. Peter sandstone and between the St. Peter sandstone and the Jordan sandstone was semi-quantitatively measured by conducting two short-term aquifer pumping tests at St. Louis Park's well field at 29th Street and Idaho Avenue.

The purpose of this Phase I report is to summarize and interpret the data collected during Phase I of the study. The data collected and quality control methods used in Phase I of the study are also generally summarized in this report. Additional details regarding data collection methods can be found in the various investigative memoranda that were prepared during the coarse of Phase I or in the reports furnished by the subcontracting laboratories included in Appendices A, B and C of this report. After the data collected during Phase I has been reviewed, the additional data collection activities necessary to attain the first three objectives of the study will be defined and carried out. Concurrently with carrying out the additional data collection activities, work will be concentrated on predicting the effect of the wastes on the surficial and bedrock ground water systems and on evaluating techniques to mitigate the impact of the wastes.

SOIL INVESTIGATIONS

OVERVIEW

The objectives of the soil investigations carried out in Phase I of the study were to:

a. collected soil samples for chemical analyses to generally define the vertical and horizontal extent of coal-tar-derived wastes in the glacial soils,

b. better define the stratigraphy of the soils overlying bedrock in the study area and

c. collect soil samples to generally define the permeabilities of the aquifers and confining strata in the soils overlying bedrock.

In Phase I of the study, a total of fourteen soil borings were placed at the locations shown in Figure 1.* Two soil borings were randomly placed in the northern one-half of the site, six borings were specifically placed in areas on the site suspected of being saturated with coal-tar derivatives during operations at the site and the remaining six borings were placed south of the site in drainageways or catchment areas for wastes that left the site during operation of the coal-tar distillation and wood preserving facility. The placement of Phase I soil borings in known or suspected areas of coal-tar waste was selected over placement of Phase I borings in a general grid pattern over the study area to concentrate the Phase I efforts in areas with the highest subsurface contamination potential.

Soil samples were typically collected approximately every 5 feet throughout the soil column at each boring during the Phase I soil investigation. Where coal-tar wastes were visibly present, samples were often collected at 2-1/2 foot intervals. The length of the actual soil sample varied from 6 inches to 18 inches depending on the amount of sample retained in the sampler. With the exception of Boring 2 and Boring 7, all soil borings were placed to bedrock. A total of 196 soil samples were collected during the Phase I soil investigation.

SOIL SAMPLING METHODS

The requirements of the soil sampling program and the nature of the soils in the study area required that a certain amount of experimentation be carried out during the early stages of the Phase I soil boring program. The purposes of this portion of the report are to summarize the requirements for collecting representative soil samples and to summarize the methods used to place the soil borings and collect the soil samples. The sample collection methods are discussed in detail to demonstrate the care used to collect a representative soil sample.

The following five general requirements were identified as being important in collecting a representative soil sample for this study:

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*All figures and tables are included in the section labeled Figures and Tables preceding the Appendices to this report.

a. The soil sampler must be clean prior to collection of the soil sample.

b. The clean sampler must be transmitted to the sample collection point in a condition that will not contaminate the sample.

c. Contamination of the soil sample must not occur while the sample is still in place.

d. Contamination of the soil sample must not occur while the sampler is being withdrawn from the point of sample collection.

e. Miscellaneous sources of sample contamination must be minimized.

A variety of soil boring and soil sampling methods were tried before arriving at the method that best satisfied the requirements outlined above. The soil sampling procedures used in Soil Borings 1, 2 and 3 utilized a standard split-barrel sampler conforming to ASTM D-1586-67. The boring was advanced between sampling points with a hollow stem power auger. The split-barrel sampler was lowered through the hollow stem of the auger to collect the soil sample. Prior to beginning each soil boring, the samplers were washed with city water, rinsed with distilled-deionized water, rinsed with acetone and rinsed with hexane. In soils with no visual evidence of organic material (natural or coal-tar derived), the sampler was washed with city water and rinsed with distilled-deionized water after each soil sample was removed from the sampler. In organic soils or in areas where visible coal-tar wastes were present, the sampler was washed with city water, rinsed with distilled-deionized water, rinsed with acetone and rinsed with hexane after each soil sample was removed. Prior to lowering the split-barrel sampler to the point of sample collection, the opening at the bottom of the driving shoe was tightly plugged with a neoprene plug and the sampler was filled with distilled water to keep potentially contaminated ground water out of the sampler. The sampler was then lowered through the hollow stem of the auger and a soil sample was collected. As the soil sample entered the sampler, the neoprene plug was pushed into the sampler ahead of the soil sample. Contamination of the soil sample was minimized as the sampler was being withdrawn by using various sampler modifications to retain as much of the soil sample as possible within the sampler and by minimizing water pressure on the sample. In addition, the following precautions were used to insure that miscellaneous sources of contamination were minimized:

a. Only glass sample containers cleaned with distilled-deionized water, acetone washed, hexane-double-rinsed with caps lined with aluminum foil were used.

b. The drilling equipment was steam cleaned before beginning the project.

c. No solvents or greases were used on the auger or drilling equipment.

d. No smoking was permitted within 100 feet of the work area.

e. Clean work gloves were used at the start of each day.

f. Soil samples were frozen at the end of each day and kept frozen until analyzed.

To insure that the soil was not contaminated below the base of the auger, no jetting was initially allowed during placement of the boring. Difficulties were encountered in keeping the sands encountered in the study area from backing up into the auger at depths in excess of 20 feet below the surface of the glacial drift ground water system. The back-up of sand into the auger precluded the collection of an undisturbed soil sample from below the auger. A number of techniques were tried to minimize the back-up of soil into the auger. These techniques included maintaining the water level in the hollow stem of the auger at or above the glacial drift ground water table, advancing the auger with a bottom plug and finally jetting with a variety of bits.

The most troublesome problem encountered with the soil sample collection procedure used on Borings 1, 2 and 3 was soil backing up into the auger. In fine to medium sand, the soil pressure plus the water pressure outside of the auger could not be equalized by adding water to the inside of the auger. Plugging the hollow stem of the auger was also not effective and the degree of jetting that was often found to be necessary to clean the auger may have been sufficient to change the chemical concentration of the soil sample prior to collection. To overcome this problem, the soil boring procedure was modified as follows and the modified procedure was used to place Borings 4, 5 and 7:

a. A positive pressure at the base of the hollow stem auger was maintained with a bentonite drilling fluid, rather than with water.

b. The split-barrel sampler was replaced with a thin-wall piston type sampler.

This method was more effective than the previous method; however, soil still often entered the auger at depths greater than 20 feet below the water table. In addition, the piston sampler required a great deal of maintenance since, due to soil conditions, the sampler had to be driven instead of being hydraulically pushed into the soil.

To overcome these problems, the soil boring procedure was further modified as follows for the remaining eight soil borings:

a. The hollow stem auger was replaced with a rotary casing below the water table to eliminate the inflow of fine sand through joints in the auger.

b. The piston sampler was replaced with a standard split-barrel sampler with an 18-inch long interior brass liner for sampling below the water table and with a standard thin-wall sampler for sampling above the water table.

Thin-walls and split-barrel liners were cleaned in the laboratory by washing and rinsing several times with clean water prior to being transported to the field. Where visible coal-tar wastes were present, the thin-walls and liners were rinsed with triethane and alcohol. In the field, the split-barrel sampler was washed and rinsed with clean city water after each soil sample was collected.

Above the saturated zone, a hollow stem auger was used as a casing for the sampler. When the saturated zone was reached, the hollow stem auger was replaced with 4-inch diameter casing. "NX" size casing was then lowered inside the 4-inch casing and a clean bentonite slurry was added to maintain a positive pressure at the base of the casing. The split-barrel sampler with brass liner was lowered through the drilling fluid to the sampling point. Bentonite filled the sampler as the sampler was lowered; however, the bentonite slurry was forced out of the sampler as the soil sample entered the sampler. Based on visual examination of the samples, bentonite was typically not present on the sides of the sample and never penetrated more than approximately 3 inches into the top or the bottom of the soil sample. This observed depth of bentonite penetration agreed with observations reported in the literature(1).* The portion of the soil sample visibly affected with bentonite was not retained for analysis. Bentonite contamination of the sample, however, was a concern and a chemical analysis of the bentonite slurry from a typical boring was carried out. The results of the analysis are discussed in the next section of this report. The bentonite slurry and the rotary casing helped prevent sand from entering the casing. Fine sands, however, occasionally entered the casing even when bentonite slurry was used. Also, coarse sand and gravel occasionally collected in the casing as the casing was advanced. Under both of these conditions, the casing was cleaned using a tricone roller bit and the soils were removed with the bentonite slurry. The bentonite slurry was not recirculated, but was wasted on the ground near each boring. When the bentonite slurry was used, sample retention improved significantly over retention when bentonite was not used.

Ambient air temperatures were sub-freezing during the time this procedure was used. Samples retained in the thin-walls and in the brass liners were allowed to freeze and the samples remained frozen until extracted in the laboratory. In the laboratory, the samples were visually classified and immediately transferred to glass containers. The samples were then frozen until the chemical analyses were performed.

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*All references are included at the end of the text of this report.

GEOLOGIC INTERPRETATION OF SOIL SAMPLES

The visual classifications and the elevations of each soil sample collected during Phase I are illustrated in Figures 2 through 8. No attempt has been made to extrapolate soil conditions vertically between soil samples in these figure ; however, the data does show that stratigraphy in the area is extremely complex with soils ranging from coarse sands and gravels to till containing appreciable quantities of silt and clay. In general, glaciofluvial sediments, glacial till and lacustrine sediments were revealed by the soil borings. At least two types of till were identified, each with an associated outwash.

The following sequence of events likely occurred during the glacial period. The Superior lobe advanced from the northeast in a southwesterly direction during the St. Croix phase. The termination of the Superior lobe is marked by the St. Croix moraine which is partially obscured by younger glacial drift in the Twin Cities area. The soil borings in the study area indicate that the till associated with the advance of the Superior lobe rests either directly on bedrock or over thin granular sediments, possibly pre-glacial in origin. The Superior lobe till is generally overlain by 10 to 30 feet of outwash and ice contact deposits in the study area, with boulders and large cobbles frequently encountered in the ice contact deposits. Glacial till above the Superior lobe till is associated with the Granstburg sub-lobe of the Des Moines lobe. The Grantsburg sub-lobe advanced from the southwest to the northeast and terminated northeast of the Twin Cities near Grantsburg, Wisconsin. The Grantsburg sub-lobe till is generally covered with a relatively thick sequence of outwash and ice contact deposits. A generally north-south trending linear deposit of lacustrine sediment occurs through the center of the former coal-tar distillation and wood preserving facility and extends south of the site, broadening south of T.H. 7. Approximate limits of this deposit are shown in Figure 9. A typical east-west geologic section through the glacial deposits across the site is shown in Figure 10.

The soil data in Figures 2 through 9 presents a discontinuous picture of the soil column at each boring. In order to help obtain a better understanding of the soil stratigraphy in the study area, the borings and the glacial history of the area were used to develop six generalized geologic sections through the soil borings placed in Phase I of the study. These generalized geologic sections should be viewed as a reasonable estimate of the stratigraphy of the glacial soils based on the limited data that is presently available. Many more soil borings with continuous soil sampling or the application of other geological exploration techniques will be needed to accurately define the complex soil stratigraphy beneath the site.

Generalized geologic sections A through F, interpreted from the soil samples and the glacial history of the study area, are shown in Figures 15 through 26. The location of the geologic sections are shown in Figures 11 and 12. The six geologic sections illustrate the discontinuity and lensing of the soils in the study area. Although the glacial till strata are shown as essentially continuous on the geologic sections, the borings and soil samples indicate that the thickness and composition of the till strata varies considerably. The soil samples, for example, indicate that the thickness of the glacial tills varies from 6 inches to 15 feet and several till samples were characterized by fines in the silt size range with little or no clay size material. Because the till was found to be extremely thin in places, it is entirely possible that the till strata are missing in places and are not as continuous as shown on the geologic sections. It is also possible that some till stata were missed with the soil sample collection spacing of 5 feet.

A generalized bedrock column is shown in Figure 13. Bedrock geology in the study area consists of a series of nearly horizontal sedimentary formations. The meager bedrock samples collected at the base of some soil borings indicate that the Platteville limestone is typically the uppermost bedrock unit. The last sample from Boring 1 included chips of St. Peter sandstone; however, it is not possible to determine if the St. Peter sandstone is actually the uppermost bedrock formation in this area or if a sandstone boulder was encountered. The elevation of the last sample from Boring 1 indicates that the Platteville limestone should be the uppermost bedrock unit at this boring. Areas where the St. Peter sandstone is the uppermost unit are, however, known to occur near the study area and these buried bedrock valleys are potential areas of increased vertical ground water movement. Areas approximately 1 mile to the north and 1 mile to the east have been shown to have St. Peter sandstone as the uppermost unit. More information on the buried bedrock valleys as well as detailed descriptions of the bedrock aquifers are discussed in a previous report completed in the study area.[2]

CHEMICAL ANALYSES OF SOIL SAMPLES

In order to help design the chemical analysis portion of the Phase I study, two samples of concentrated coal-tar derived wastes were analyzed using mass spectrometry gas chromatography techniques. These two samples were collected from the northern edge of the storm water storage pond on the site during pond construction. Adequate clean-up procedures were not used to quantify all compounds in the samples, but the mass spectrometry/ gas chromatography analysis revealed the presence of polynuclear hydrocarbons in the solid and liquid portions of the samples. The laboratory report of the analyses is included in Appendix A of this report.

Based on prior work carried out in the study area and based on the limited results of the analysis of the two concentrated waste samples, the chemical analysis of soil samples in Phase I of the study was divided into the following two basic programs:

a. The concentrations of phenolic material and benzene extractable material in all soil samples collected during Phase I were measured as a gross indicator of the relative amount of coal-tar derived wastes present in the soil samples.

b. Qualitative thin-layer chromatography techniques and quantitative gas chromatography techniques were applied to selected soil samples to determine the degree to which polynuclear organic materials were present in the soil samples.

Phenolic and Benzene Extractable Analyses

The level of phenolic material in each soil sample was measured on a 3 to 5 gram soil sample using the Distillation Chloroform Extraction procedure contained on pages 501 through 506 of Standard Methods for the Examination of Water and Wastewater, 13th Edition. An April 20, 1970, memorandum to the Minnesota Pollution Control Agency from the Minnesota Department of Health concluded that this general method of phenolic determination was adequate to measure phenolics discharged in creosoting wastes from the site, based on a limited amount of comparative testing carried out in the Health Department's laboratory.[3] The detection limit for this phenolic analysis procedure was approximately 0.2 mg/kg (wet weight) when applied to the soil samples. Benzene extractable material was measured by extracting a 20 gram soil sample with benzene in a Soxhlet extraction apparatus for four hours and measuring the total weight of material extracted. Except for the use of benzene as the solvent, the analytical procedure used to measure the concentration of extractable material was the same as the Soxhlet extraction procedure given on page 412 of Standard Methods for the Examination of Waste and Wastewaters, 13th Edition. Extracted material was reported in milligrams of extracted material per kilogram of sample. The detection limit for the benzene extractable analyses was 50 mg/kg (wet weight).

To measure the concentration of phenolic material and benzene extractable material, a 100 gram sub-sample was taken from each soil sample and the sub-sample was quartered to obtain a 25 gram sample. Twenty grams of the quartered sub-sample were used in the analysis for benzene extractable material and 3 to 5 grams of the quartered sub-sample were used in the analysis for phenolic material.

To obtain the moisture content and, therefore, the dry weight of the soil sample, a quarter of the sub-sample was oven dried at 105°C to a constant weight. The loss of hydrocarbons by oven drying the samples at 105°C was defined by comparing the moisture content obtained by oven drying with the moisture content obtained by air drying. As discussed in Appendix B, no significant differences in moisture contents were found using the two methods.

Because of the unknown reproducibility of data from the benzene extractable and phenolic analyses when the analyses were applied to soil samples from the study area, replicate samples were analyzed to demonstrate the degree of data reproducibility. On approximately 10 percent of the soil samples, a second quarter of the sub-sample was analyzed for phenolic and benzene extractable materials as well as percent solids. The results of these analyses are summarized in SERCO Laboratories' report contained in Appendix B of this report. In general, the relative standard deviations of the percent solids and phenolic analyses were .8 percent and 1 percent, respectively, and the relative standard deviation of the benzene extractable analysis was 37 percent. Thus, data from the analysis for phenolic material exhibited better reproducibility than data from the benzene extractable analysis.

The influence of the bentonite drilling fluid on the soil samples was a concern when the soil sample collection techniques using bentonite were introduced. A chemical analysis of a bentonite sample obtained from Boring 10 indicated a phenolic concentration of .02 mg/l and a benzene extractable concentration of 24 mg/l. These concentrations were used to calculate the effect of saturating a soil sample with this bentonite. Sand and gravel would be the soil types potentially most affected by the bentonite drilling fluid because of the relatively large pore spaces and permeabilities of these soils compared to fine sand, silt and clay. A typical kilogram of sand was assumed to occupy approximately 520 cubic centimeters and have a porosity of approximately 30 percent. If the sand sample was completely saturated with bentonite drilling fluid with a phenolic concentration of 0.02 mg/l and a benzene extractable concentration of 24 mg/l, the calculated concentration of phenolic material in the soil sample would be .003 mg/kg and the calculated concentration of benzene extractable material would be 4 mg/kg. Both of these concentrations are well below the detection limits used in the analyses of these two parameters in this study.

Discussion of Phenolic and Benzene Extractable Data

SERCO Laboratories' report summarizing the phenolic and benzene extractable concentrations of the soil samples collected for the Phase I study is included in Appendix B. The laboratory report also includes a detailed discussion of the analytical methods used to measure the concentration of phenolic and benzene extractable materials, the results of the replicate sample analyses and the conclusions drawn from special studies carried out to develop the analytical procedures.

The phenolic and benzene extractable concentrations in the samples collected from each soil boring are illustrated in bar graph format in Figures 2 through 8. The moisture contents were used to reduce all data to a dry weight basis and all concentrations of phenolic and benzene extractable material presented in this report are in units of milligrams of phenolic or benzene extractable material per kilogram of sample (dry weight) unless otherwise noted. Figures 2 through 8 illustrate the changes in phenolic and benzene extractable materials with depth in each soil column. In general, the data indicates that concentrations of phenolic and benzene extractable materials are detectable in samples collected in the northern portion of the site; however, the concentrations are typically lower in the northern portion of the site than in samples from the southern portion of the site and in samples collected south of the site between Walker Street and Lake Street. The data also indicates the highest concentrations of phenolic and benzene extractable materials are typically present in the upper portions of the glacial soils on the southern portion of the site and more generally throughout the entire soil column in many areas south of the site between Walker Street and Lake Street. In addition, phenolic concentrations between T.H. 7 and Lake Street were detected at high levels immediately above two confining layers approximately 30 and 50 feet below the ground surface. For example, between T.H. 7 and Lake Street, a phenolic concentration of 7.8 mg/kg, and a benzene extractable concentration of 1,740 mg/kg were measured in samples collected at a depth of 49 feet. These high concentrations are overlain by lower phenolic and benzene extractable concentrations as well as by soil strata with low permeabilities. A detailed discussion of the phenolic and benzene extractable data obtained from soil samples is included in Appendix D of this report.

In visually classifying the soil samples from the fourteen borings, a number of samples saturated with a visible black liquid with a creosote-like odor were noted. The borings which produced soil samples saturated with the visible black liquid and the range in depths at which the saturated samples were found are illustrated in Figure 14. As shown in Figure 14, the soil samples saturated with the black liquid were typically not found in borings placed in the northern portion of the site, were collected from the upper soil strata on the southern portion of the site and were collected from increasingly greater depths south and southeast of the site. It is interesting to note that the concentrations of phenolic and benzene extractable materials in the soil samples saturated with the black liquid varied considerably, as shown in Figures 2 through 8. According to laboratory personnel, a distinctive black color remained after the samples were extracted to a constant weight.

As discussed previously, a number of geologic sections were drawn through the various soil borings placed during the Phase I study. The measured concentrations of phenolic and benzene extractable material were plotted at each boring location in the vertical position where each soil sample was collected. The chemical data was then used to draw contours of equal benzene extractable concentrations and equal phenolic concentrations on each geologic section. These contours are illustrated in Figures 15 through 26. Data such as the location of till strata, the location of coarse granular soils and the direction of ground water movement were not used to construct the concentrations contours, due to the sketchy nature of the geologic data collected to data and due to the desire not to bias the chemical contours at this time. The concentration contours drawn on the geologic sections indicate generally increasing concentrations of both phenolic and benzene extractable material with increasing depth in a southerly and southeasterly direction from the site. The chemical contour data should be viewed as a means of generally interpreting the chemical data collected from the soil samples to date. The contours are most useful in obtaining a general picture of changing phenolic and benzene extractable concentrations across the study area. The contours must be cautiously used when attempting to define conditions in a specific area not adjacent to a soil boring due to the spacing between borings and due to the wide variation in phenolic and benzene extractable concentrations within the soil profile.

The phenol and benzene extractable concentrations measured by Soil Exploration Company for the City of St. Louis Park in 1975 and 1975[4] were compared to the concentration contours and the 1974-1975 data indicated close agreement with the data collected in the Phase I study. Data reported by Soil Exploration Company from the area south of Lake Street indicated that benzene extractable concentrations as high a 1,265 mg/kg and phenolic concentrations as high as 1.3 mg/kg were found in the top 8 feet of soil in this area. This soil had been removed and placed in the area between T.H. 7 and Lake Street prior to the placement of the Phase I boring south of Lake Street.

Thin Layer Chromatography/Gas Chromatography Analyses

In addition to the analyses of phenolic and benzene extractable materials discussed in the preceding section, eleven soil samples were analyzed using thin layer chromatography techniques to qualitatively determine the presence or absence of polynuclear organic materials in the samples. Gas chromatography techniques were then carried out on five of the samples to quantitatively define the concentrations of the various polynuclear organic materials that were present. The objective of the thin layer chromatography/gas chromatography analyses was to begin defining the extent to which the polynuclear organic materials are moving from the visible deposits of coal-tar wastes identified in the various soil borings.

A total of eleven soil samples collected from Borings 5, 9 and 11 were selected for thin layer chromatography analysis. The following paragraphs briefly discuss the reasons for selecting soil samples from these three borings.

a. Boring 5 - Boring 5 was located immediately northeast of the new storm water storage pond on the site in the area of a former API Separator where coal-tar derivatives are known to exist above the saturated zone. Coal-tar wastes could be seen seeping from the banks of the storm water storage pond during pond construction in late 1975. A soil sample from the 5 foot depth of Boring 5 with the characteristic black color and creosote-like odor was selected for analyses by thin layer chormatography techniques. In addition, a soil sample collected immediately below the top of the saturated zone at a depth of 15 feet and a soil sample collected at a depth of 30 feet were also selected for analyses by thin layer chromatography techniques. The two deeper samples did not contain visible coal-tar waste.

b. Boring 9 - In Boring 9, surface peat and an organic silty clay strata overlie a zone of sand visibly saturated with coal-tar waste immediately above a till stratum approximately 32 feet below the ground surface. A second stratum of sand visibly saturated with coal-tar waste was found immediately above a second till layer at a depth approximately 48 feet below the ground surface. One sample from the overlying peat, two samples from the sands overlying the two till layers and two samples from the two till layers were selected for analysis using thin layer chromatography techniques.

c. Boring 11 - Soil samples from Boring 11 did not indicate visible saturation with coal-tar wastes between the ground surface and bedrock although a creosote-like odor was detected. The till strata indicated in Boring 9, however, were also identified in Boring 11, and soil samples were selected from the strata where coal-tar wastes were present in Boring 9 for analysis by thin layer chromatography techniques.

The eleven soil samples outlined in the preceding paragraphs were examined for polynuclear organic materials by Midwest Research Institute (MRI) at their Kansas City, Missouri, laboratory. Soils were extracted with cyclohexane and the extracts were screened by thin layer chromatography on silica gel. Development with 1.5:1 (v/v) benzene-cyclohexane and visualization under long ultraviolet light indicated that polynuclear organic materials were present in all samples with the highest concentrations in samples from the shallow stratum of Boring 5 and from the two coarse sand strata above the till layers in Boring 9. Thin layer chromatography plates for five soil extracts were scraped and reextracted for gas chromatographic examination. The polynuclear organics, anthracene, 3-methyl cholanthrene and 3,4,5,6-dibenzcarbazole were not identified in any extract; however, benz(c)phenanthrene, chrysene, and benz(a)pyrene were measured in some soil samples. Several unassigned peaks on the gas chromatograph traces indicated notable quantities of other polynuclear organic material that could not be identified with standards available at MRI. The results of the thin layer chromatography and gas chromatography study as well as the phenolic and benzene extractable concentrations measured on the eleven soil samples sent to MRI are summarized in Table 2.

The results of the thin layer chromatography and gas chromatography analyses as well as the phenolic and benzene extractable concentrations measured on the eleven soil samples sent to MRI are summarized in Table 2. The data indicates that polynuclear organic material was present in all eleven soil samples with significantly high concentrations present in the visibly contaminated soil samples at depth in Boring 9 and from the surface of Boring 5. The soil samples that include the letters A and B from Boring 9, are samples where the coarse sand-till interface was actually present in the sample. Samples SS-109B-1 and SS-109A-2 were collected from the coarse sands overlying the till strata and samples SS-109A-1 and SS-109B-2 were collected from the till strata underlying the sands. Much greater quantities of benz(c)phenanthrene, chrysene and benz(a)pyrene were found in the sands overlying the tills than in the tills themselves. Chrysene measured in the coarse sand overlying the till at a depth of 50 feet in Boring 9 was 474.5 μg/gm, and benz(a)pyrene was measured in the same soil sample at 6.9 μg/gm. Both of these compounds were below the detection limits in the till stratum underlying this sample. Benz(a)pyrene and chrysene were also detectable in the coarse sand stratum at a depth of approximately 32 feet overlying the upper till stratum in Boring 9. Concentrations of these two compounds were also below the detection limits in the till underlying this sample.

Midwest Research Institute's report, including a discussion of analytical procedures, a summary of results and appendices containing the thin layer chromatographic screens and the gas chromatograms of the quantified extracts, is included in Appendix C of this Phase I report. The quantification of polynuclear organic materials deep in the soil column south of the site is one of the most significant findings of the Phase I study. The data indicates that the polynuclear organic materials are being concentrated above the till strata and that polynuclear ogranic materials have moved below the upper till stratum in the glacial soils.

GROUND WATER INVESTIGATIONS

OVERVIEW

Available data regarding ground water gradients and ground water quality in the study area was collected almost entirely from the large number of municipal and industrial bedrock water supply wells existing in the area. Virtually no reliable data is available on surficial ground water gradients or on ground water quality in the study area. The ground water investigation carried out during the Phase I study concentrated on defining the gradients and quality of the surficial ground water system. Nine shallow ground water monitoring wells were placed over the study area and were used to collect data on ground water levels and to collect ground water samples. The samples were analyzed for various parameters including phenolics, benzene extractable material, specific conductance and total dissolved solids that will generally indicate the effect of the coal-tar wastes on the quality of the surficial ground water system. A limited number of samples were also collected from existing municipal and industrial water supply wells in the study area to generate additional data on the level of indicator parameters in the bedrock ground water aquifers.

PLACEMENT OF MONITORING WELLS

The locations of the nine ground water monitoring wells installed during the Phase I study are shown on Figure 27. Three of these wells are located on the site and six wells are located around the site with two tiers of wells located to the south. The monitoring wells are constructed according to the procedures outlined in the Minnesota Water Well Construction Code except that the wells were not chlorinated after development. Each well is constructed of 4-inch diameter black steel pipe with 4 feet of stainless steel well screen. A cross-section through a typical Phase I monitoring well is shown in Figure 28.

The elevation of the top of the well, the elevation of the bottom of the well screen and pertinent data regarding the soils encountered during well placement are summarized in Table 2. Since the Phase I study concentrated on defining the ground water quality and ground water gradients in the upper portion of the surficial ground water system, the well screens terminated in the first glacial drift aquifer capable of supplying 3 to 5 gallons per minute. With the exception of Well 1 and Well 7, all wells are believed to be constructed above the first major glacial till stratum. Well 1 extends approximately 5 feet into the Platteville limestone since an aquifer capable of supplying 3 to 5 gallons per minute was not found above bedrock. Well 7 terminates approximately 70 feet below the ground surface since no aquifer capable of supplying 3 to 5 gallons was encountered above that depth. The screen for Well 7 is placed below the upper glacial till stratum.

GROUND WATER DATA

Water levels in the nine wells were measured on March 25 and on May 6, 1976. Water levels measured on March 25 are illustrated in Figure 29 and water levels measured on May 6 are illustrated on Figure 30. The ground water levels indicate that the surficial ground water gradient in the study area is quite flat with a slight southerly gradient. Ground water movement in the glacial soils on the southern portion of the site and south of the site appears to be influenced by the bedrock aquifer pumping center located near the intersection of Lake Street and T.H. 7, east-southeast of the site.

Ground water samples were obtained from eight of the nine ground water monitoring wells during April, 1976. A ground water sample could not be obtained from Well 3, located on the northern portion of the site, since the well was destroyed during grading in the area. This well has since been replaced and was sampled on May 13, 1976, but the data was not available for the Phase I report. In addition to the eight ground water monitoring wells, samples were also collected from St. Louis Park City Wells 1, 3, and 10 (CW-1, CW-3 and CW-10 on Figure 27) located at the City's well field at 29th Street and Idaho Avenue, from the Flame Industries well and from the Midco Register well (formerly Robinson Rubber Co.). The locations of these municipal and industrial wells are also shown on Figure 27.

The Phase I ground water monitoring wells were pumped with a submersible pump for a 2-hour period prior to collecting the water samples. Samples for phenolic analysis were collected in 1 liter glass containers and preserved with 5 ml of 1+9 H_3PO_4 and 5 ml of 10 percent $CuSO_4$. Samples for analysis of benzene extractable organics were collected in 1-1/2 liter glass containers that had been washed and freon rinsed. Duplicate phenolic and benzene extractable samples were collected from all wells. One set of samples was delivered to SERCO Laboratories for analysis and the set of duplicate samples was refrigerated at 4°C at Barr Engineering Co.

The samples were analyzed for total dissolved solids, hardness, alkalinity, specific conductance, phenolics, and benzene extractable material. The analysis for phenols was carried out using the Distillation Chloroform

Extraction Procedure as contained on pages 501 through 506 of Standard Methods for the Examination of Water and Wastewaters, 13th Edition. Benzene extractable analysis was performed using the Oil and Grease procedure contained on page 254 of Standard Methods, 13th Edition, with benzene as the extracting solvent. The methods used to prepare and analyze the samples are summarized in Appendix B. The quality control information for phenolics, hardness and alkalinity are also included in Appendix B.

The chemical water quality data obtained from the analysis of the water samples is summarized in Table 3. The concentration of benzene extractable material measured in the sample from Phase I Well 6 and the phenolic concentration measured in the sample from the Midco Register well could be anomalous values, when compared with the results of other data from the Phase I study and when compared with concentrations measured by the Minnesota Department of Health during 1974. Phenolic analyses carried out on the duplicate sample from Well 6 and from the Midco Register well, however, were in good agreement with the initial values as shown on Table 3. The duplicate benzene extractable samples from Well 6 and from the Midco Register well were also analyzed. The reanalysis indicated a benzene extractable concentration of 4 mg/1 in the duplicate sample from Well 6, which does not compare well with the concentration of 14 mg/1 measured in the initial sample. Reanalysis indicated a concentration of 1 mg/1 in the duplicate sample from the Midco Register well which is in close agreement with the initially measured concentration of 2 mg/1.

The following preliminary conclusions can be made regarding the data:

1. Detectable phenolics were found in samples from the Phase I monitoring wells 5, 6 and 9 and at the Midco Register well. These four wells are located either on the south site boundary or southeast of the site. No detectable phenolics were found in the Platteville well located northeast of the site, in Well 7 located in the glacial drift aquifer below the first glacial till stratum west of the site, in Well 2 in the upper glacial drift aquifer directly north of the site, in Well 8 directly south of the site, in Well 10 south of the Chicago & Northwestern Railroad, in the Flame Industries well or in

the City wells. The detectable phenolic concentrations, in general, corresponded with the general surficial ground water gradients discussed in the preceding paragraphs.

2. Detectable benzene extractable material was found in Phase I monitoring wells 2, 5, 6, and 9 and in the Midco Register well. With the exception of Phase I Well 2, which indicated a benzene extractable organic concentration above the detection limit but a phenolic concentration below the detection limit, all wells indicating detectable phenolic concentrations also indicated detectable benzene extractable concentrations.

3. The general ground water quality data indicates that the specific conductance of ground water in the sands and gravels above the upper till stratum in the study area is generally greater than 1,000 μmho/cm while the water in the bedrock aquifer and in the glacial drift aquifer below the upper glacial till stratum typically exhibits a specific conductance below 800 μmho/cm.

AQUIFER INTERACTION INVESTIGATIONS

OVERVIEW

The glacial soils in the study area are characterized by a complex system of glacial till, outwash and ice contact deposits with little consistent pattern to the aquifers and aquitards. Bedrock in the study area, on the other hand, is characterized by a series of nearly horizontal aquifers separated by aquitards. Characteristics of the bedrock aquifers are typically better defined in the literature than are the characteristics of the bedrock aquitards. The major aquifers present in the study area are the St. Peter, the Prairie-du-Chien-Jordan and the Mt. Simon-Hinckley. Several aquifers of smaller potential yield are also present, notably the Ironton-Galesville formation, the Platteville limestone and the water bearing glacial outwash and ice contact deposits in the glacial drift. Confining beds of interest in the study area are the confining members of the St. Lawrence and Eau Claire formation, a siltstone-to-shale unit near the base of the St. Peter sandstone, the Glenwood shale between the Platteville and St. Peter formations and the Superior lobe and Grantsburg sub-lobe glacial till strata.

The objective of the Phase I study of aquifer interactions was to define information on aquifer interactions available in the literature and to conduct simple pumping tests and other techniques to measure the ability of aquitards to transmit ground water. The primary emphasis of the Phase I investigation into aquifer interactions was, therefore, placed on collecting available data from the literature, broadly defining the vertical exchange of ground water through the bedrock aquitards using the City's existing well field at 29th Street and Idaho Avenue and estimating the permeabilities of the glacial soils using soil samples collected from the Phase I soil investigation.

The following paragraphs summarize known characteristics of the aquifers and aquitards present in the area, the various aquifer pumping tests performed in the Phase I study and the estimated permeabilities of the glacial soils.

GLACIAL DRIFT CHARACTERISTICS

The glacial drift aquifers are separated by the glacial tills from the Superior lobe and Grantsburg sub-lobe. The relationship of the glacial till strata and the outwash and ice contact deposits are complex and are discussed and illustrated in the section of this report summarizing the Phase I soil investigations.

Grain-size distributions were measured from ten soil samples representative of the various soil types found in the glacial soils in the study area and collected in the Phase I soil investigation. Figures 31 through 40 illustrate the grain-size distribution of these ten soil samples. The soil descriptions included with the grain-size distribution diagrams are based on a visual classification of the soils. Permeabilities for each soil sample, are also shown on the grain-size distribution diagrams. Permeabilities for the granular soils were computed from work by Hazen and permeabilities for the glacial tills were estimated from data reported in the literature.[5]

The grain-size distributions show that the glacial outwash and ice contact deposits range from a fine sand to a coarse gravel. This variation represents a potential range in permeabilities of approximately four orders of magnitude. The grain-size distributions also show that the glacial tills range from fine silty sand to a sandy clay which represents a range of permeabilities of approximately three orders of magnitude. Thus, the range of permeabilities in the glacial soils is approximately seven orders of magnitude from permeabilities of approximately 10 cm/sec for the coarse gravels to permeabilities of 10^{-6} cm/sec for the sandy clays. The location of the soil samples and permeabilities of the soils estimated from the grain-size distributions are summarized in Table 4.

One ground water monitoring well (Well 1) installed in the Phase I study, terminated in the Platteville limestone. Water levels in this well indicate that approximately 10 feet of head differential exists between the upper glacial drift ground water system and the piezometric level in the Platteville limestone in the area of Well 1.

BEDROCK CHARACTERISTICS

The characteristics of the bedrock aquifers and aquitards in the study area were defined by conducting two pumping tests designed to obtain qualitative estimates of the leakage through the Glenwood shale into the St. Peter sandstone and the vertical permeability of the formations overlying the St. Peter sandstone, in particular the siltstone unit at the base of the St. Peter sandstone. No estimates of vertical permeability of the Glenwood shale or the siltstone unit at the base of the St. Peter sandstone could be found in the literature.

Reported transmissivities for the St. Peter sandstone range from 20,000 gpd/ft. to 40,00 gpd/ft. [6] [7] and a storage coefficient of approximately 1×10^{-4} for the St. Peter sandstone was reported.[7] Transmissivities for the Jordan sandstone (excluding the Prairie-du-Chien group) range from 14,000 gpd/ft. to 80,000 gpd/ft., with an average value reported as 44,000 gpd/ft.[6] Reported storage coefficients for the Jordan sandstone range from 1.2×10^{-4} to 8.3×10^{-5} with an average value of 7×10^{-5}.[6] Reported transmissivities for the Prairie-du-Chien-Jordan range from 37,000 gpd/ft. to 198,000 gpd/ft., indicating the variable water transmitting characteristics of the Prairie-du-Chien group.[6]

Available well drilling logs indicate that St. Louis Park Wells 1, 2 and 3 either partially or fully penetrate the siltstone unit near the base of the St. Peter sandstone. In order to collect background data on piezometric fluctuations, pumping from these three wells was stopped on April 12, 1976, and the water levels in the three wells were monitored for background fluctuations. The maximum short duration fluctuation (1 to 2 hours) in water level was less than 2 inches.

On April 21, a pumping test was conducted on St. Louis Park Well 3 to qualitatively define the leakage characteristics of the Glenwood shale above the St. Peter sandstone. Well 3 was pumped at 660 gpm between 10:30 a.m. and 12:30 p.m.; the remainder of the time the well was shut-off. Water level measurements were taken before the start of pumping, during pumping and after pumping had ceased. The water level hydrographs during the recovery portion of the pumping test closely matched the water level hydrographs measured during drawdown. The data collected in the pumping test was used to calculate the transmissivity and the storage coefficient of the St. Peter sandstone, using a graphical method suggested by Boulton[8] for an aquifer with fully penetrating wells and constant discharge conditions. The data from the St. Peter pumping test best matched the non-leaky artesian type curve, indicating that the St. Peter is not being substantially recharged by leakage from the Glenwood shale in the area of the pumping test. The data collected in the pumping test was then plotted on semi-logarithmic graph paper and was analyzed using the modified non-equilibrium method suggested by Cooper and Jacob.[9] The value of the storage coefficient obtained in this analysis (9×10^{-5}), indicated that the aquifer is confined, and the transmissivity (18,000 gpd/ft.), obtained using the modified non-equilibrium method, seems to support the conclusions reached by the data from the pumping test. Although leakage and the resulting vertical permeability of the overlying Glenwood shale could not be quantitatively determined using the data generated in the pumping test, leakage from the Glenwood shale to the St. Peter sandstone appears to be quite low in the area influenced by the well field at 29th Street and Idaho Avenue, since the data fit the non-leaky type curves.

The results of this pumping test are limited since:

a. the duration of the pumping test may have been too short to measure a small amount of leakage through the confining strata,

b. the pumping test is representative of only a small area and may not be representative of conditions in other portions of the study area,

c. the actual construction of the wells may differ from the description in the well logs.

From April 12 to April 21, the St. Peter wells in the well field at 29th Street and Idaho Avenue were shut off in order to conduct a pumping test on the Jordan sandstone. St. Louis Park Well 15 is cased and grouted to the top of the Jordan formation and open hole through the Jordan. From April 12 to April 15, Well 15 was pumped at 950 gpm and a recovery type of pumping test was carried out on April 15 and 16. Well 15 was shut-off at 9:00 a.m. on April 15, and remained off until 9:00 a.m. April 16. This 24-hour period was the longest the well could be shut down. Water levels were recorded in the Jordan and St. Peter wells before the pump was shut off and for 24-hours thereafter. The data was plotted on log-log graph paper and fitted to curves for a leaky artesian aquifer with fully penetrating conditions. This analysis indicated a transmissibity of approximately 14,000 gpd/ft. and a vertical permeability of approximately 1×10^{-6} for the overlying Prairie-du-Chien group and St. Peter formation. Attempts were made to fit the data to curves based on other boundary conditions such as non-leaky artesian and leaky artesian without water release from storage in the aquitard; however, in all cases, reasonable results were not obtained for either the transmissivity or storage coefficient in the Jordan sandstone. The data from this pumping test is similarily limited, due to the same reasons listed for the St. Peter pumping test; however, the pumping test data indicates that a measurable vertical leakage is occurring into the Jordan sandstone in the area near the 29th Street and Idaho Avenue well field.

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REFERENCES

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FIGURES AND TABLES

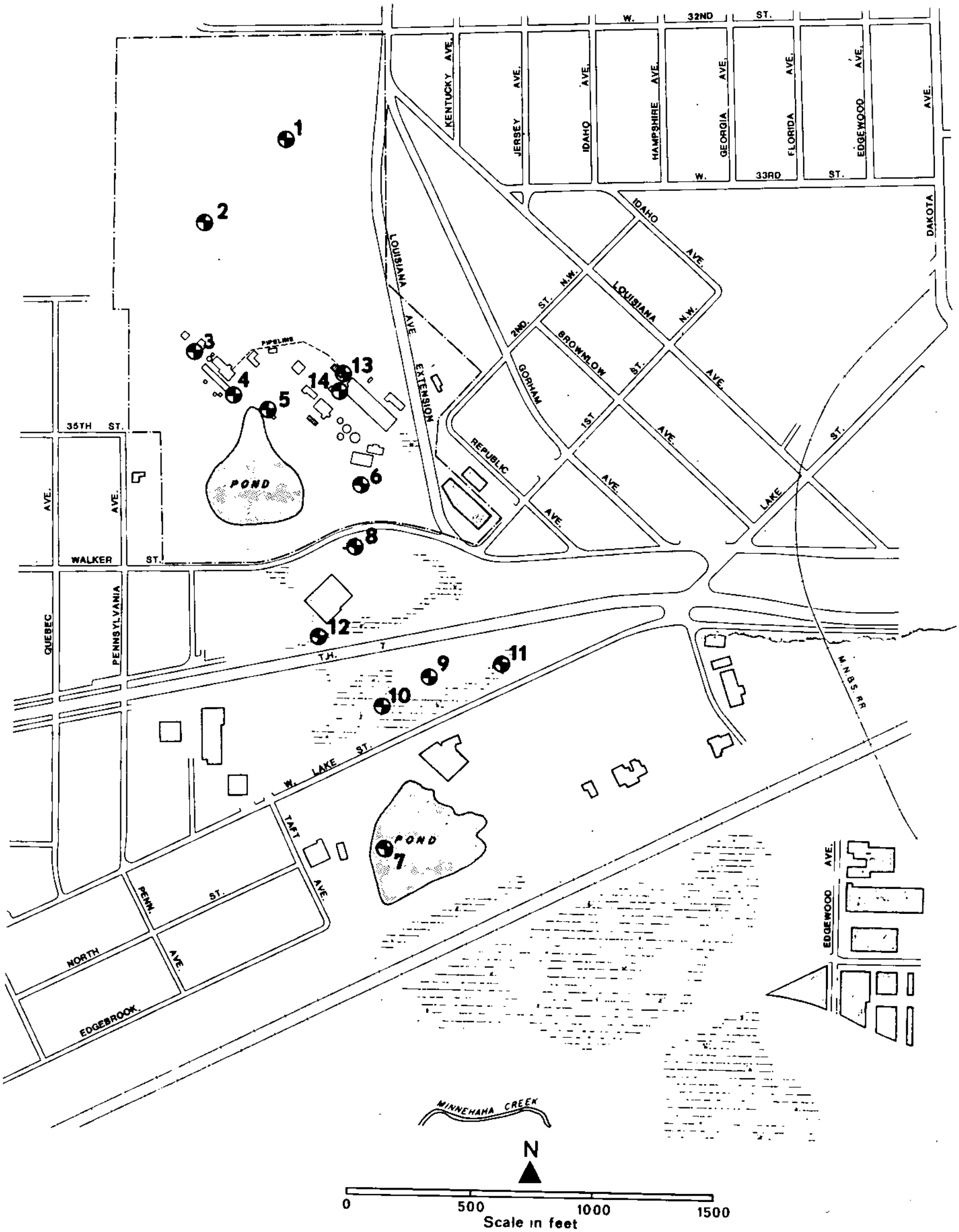


FIGURE 1
LOCATION OF PHASE I SOIL BORINGS

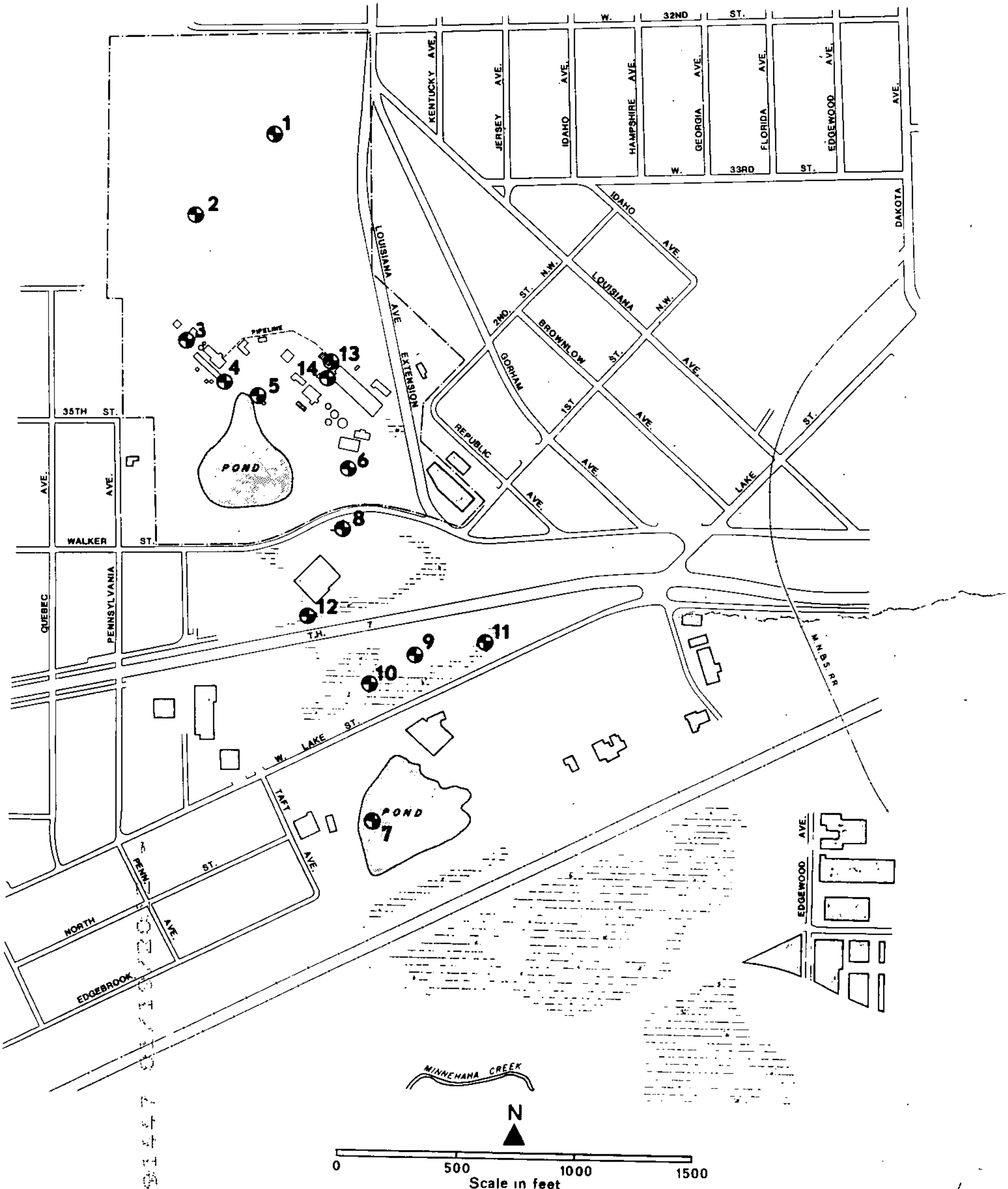


FIGURE 1

LOCATION OF PHASE I SOIL BORINGS

MINNESOTA POLLUTION CONTROL AGENCY

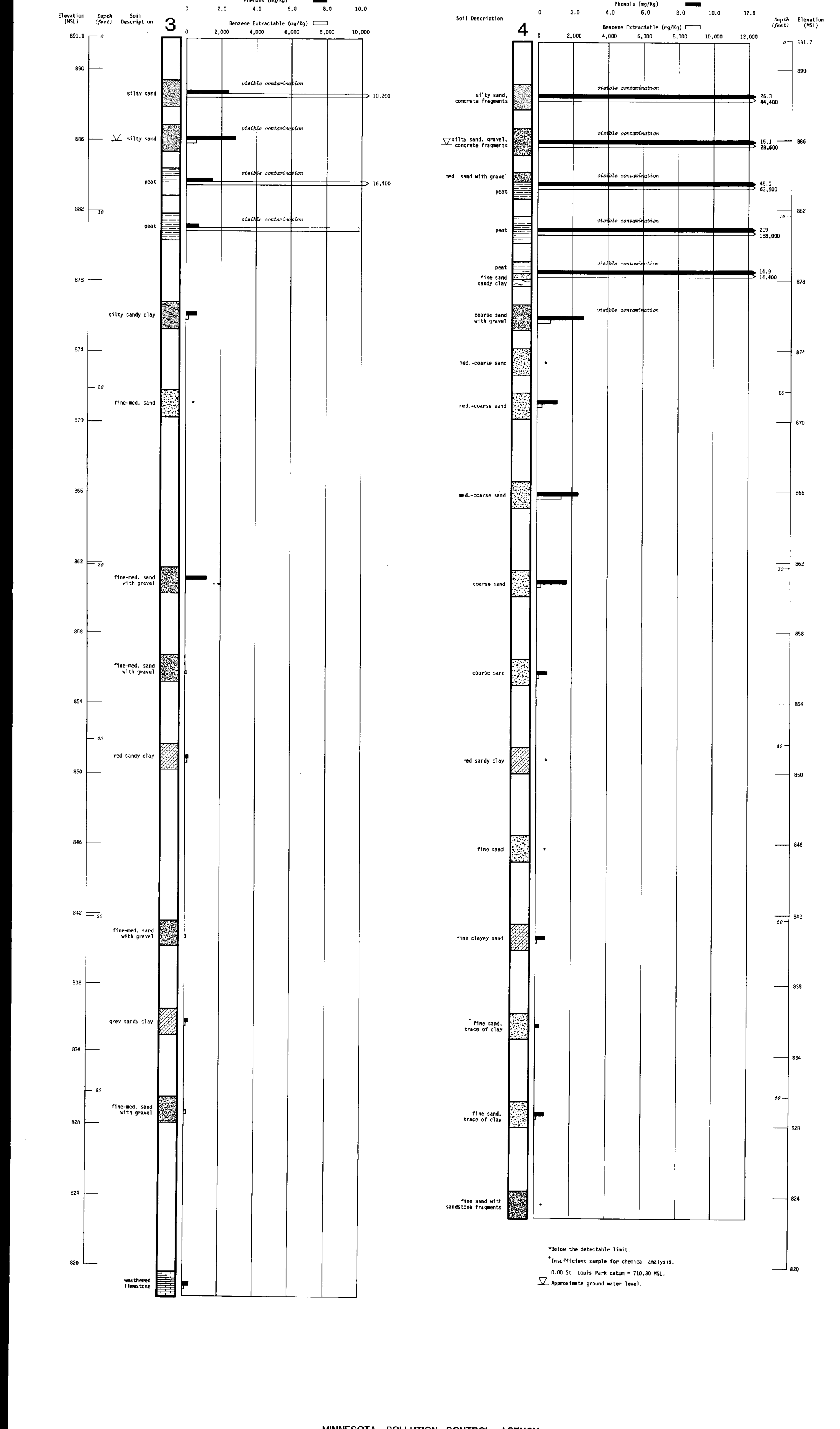
SOIL AND GROUND WATER INVESTIGATION

ST. LOUIS PARK, MINNESOTA

FIGURE 2

DISTRIBUTION OF PHENOLIC & BENZENE EXTRACTABLE MATERIAL

BORINGS 1 & 2



MINNESOTA POLLUTION CONTROL AGENCY

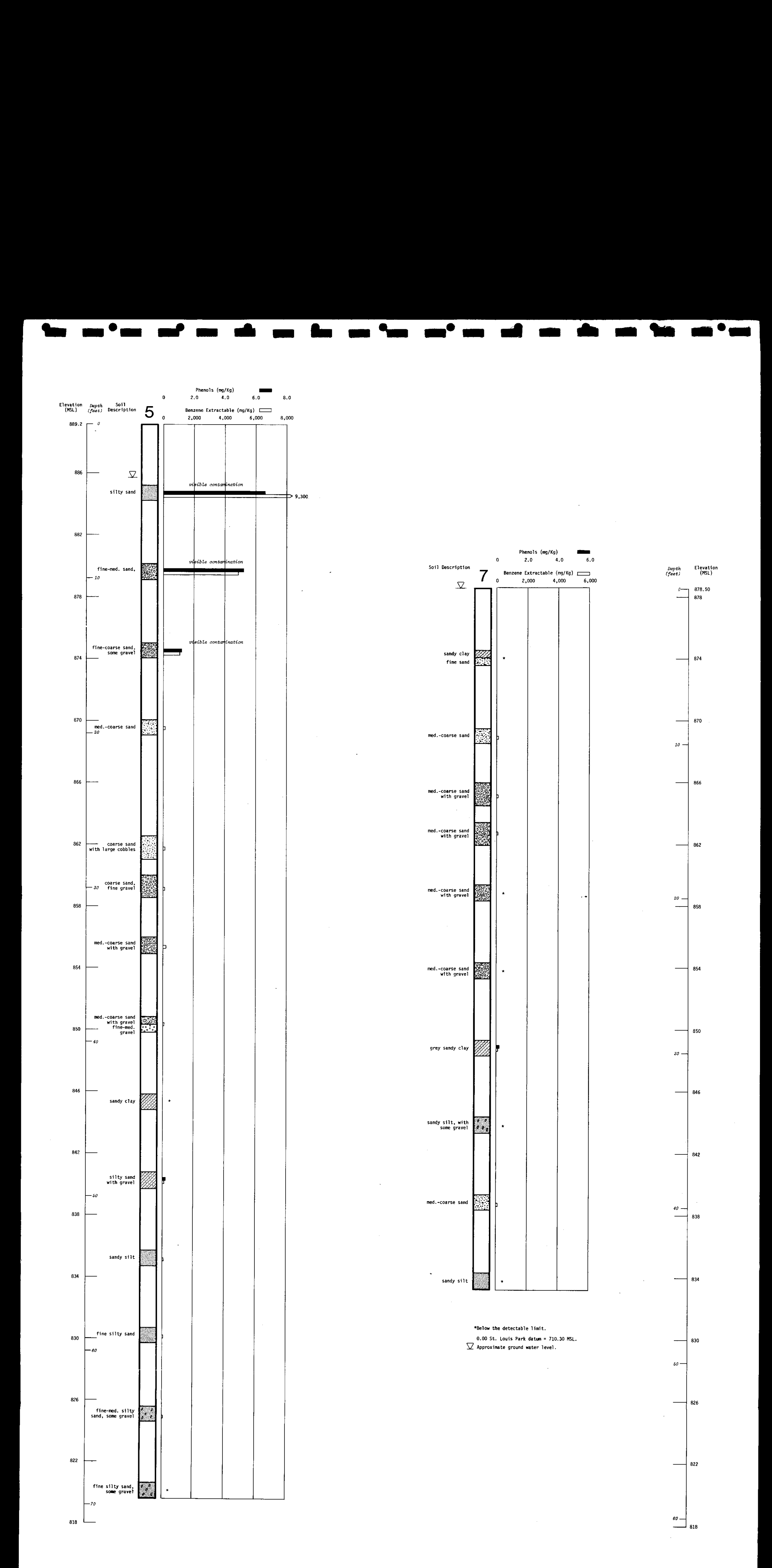
SOIL AND GROUND WATER INVESTIGATION

ST. LOUIS PARK, MINNESOTA

FIGURE 3

DISTRIBUTION OF PHENOLIC & BENZENE EXTRACTABLE MATERIAL

BORINGS 3 & 4



MINNESOTA POLLUTION CONTROL AGENCY

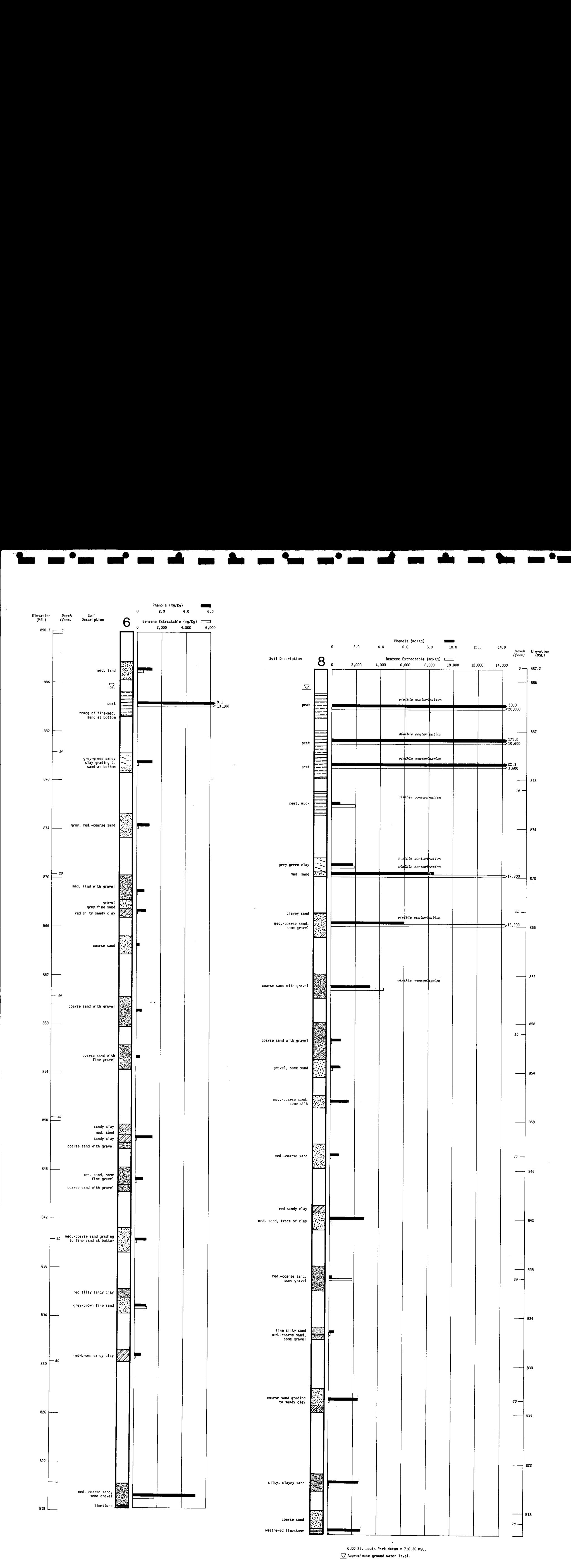
SOIL AND GROUND WATER INVESTIGATION

ST. LOUIS PARK, MINNESOTA

FIGURE 4

DISTRIBUTION OF PHENOLIC & BENZENE EXTRACTABLE MATERIAL

BORINGS 5 & 7



MINNESOTA POLLUTION CONTROL AGENCY

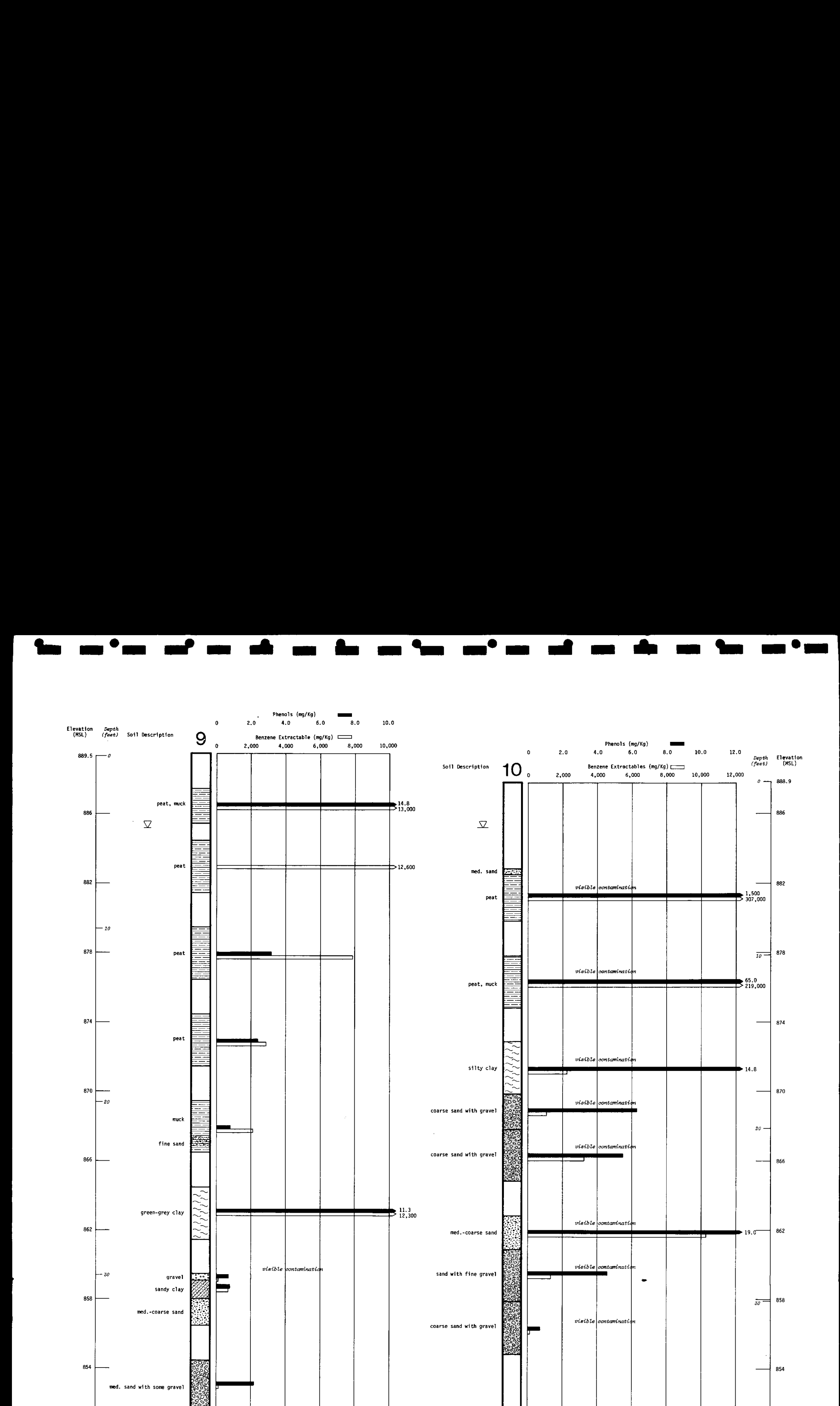
SOIL AND GROUND WATER INVESTIGATION

ST. LOUIS PARK, MINNESOTA

FIGURE 5

DISTRIBUTION OF PHENOLIC & BENZENE EXTRACTABLE MATERIAL

BORINGS 6 & 8



MINNESOTA POLLUTION CONTROL AGENCY

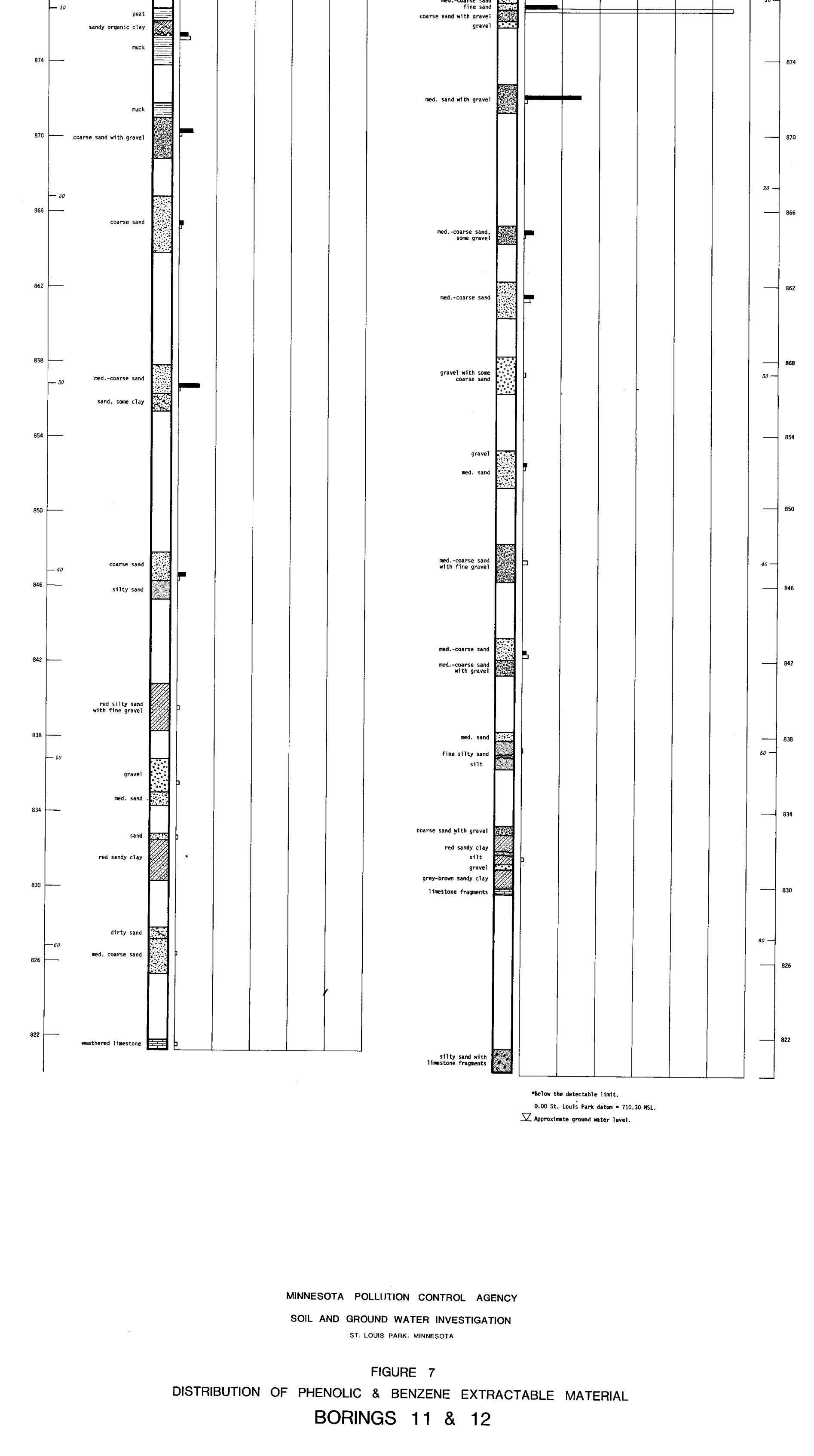
SOIL AND GROUND WATER INVESTIGATION

ST. LOUIS PARK, MINNESOTA

FIGURE 6

DISTRIBUTION OF PHENOLIC & BENZENE EXTRACTABLE MATERIAL

BORINGS 9 & 10



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SOIL AND GROUND WATER INVESTIGATION

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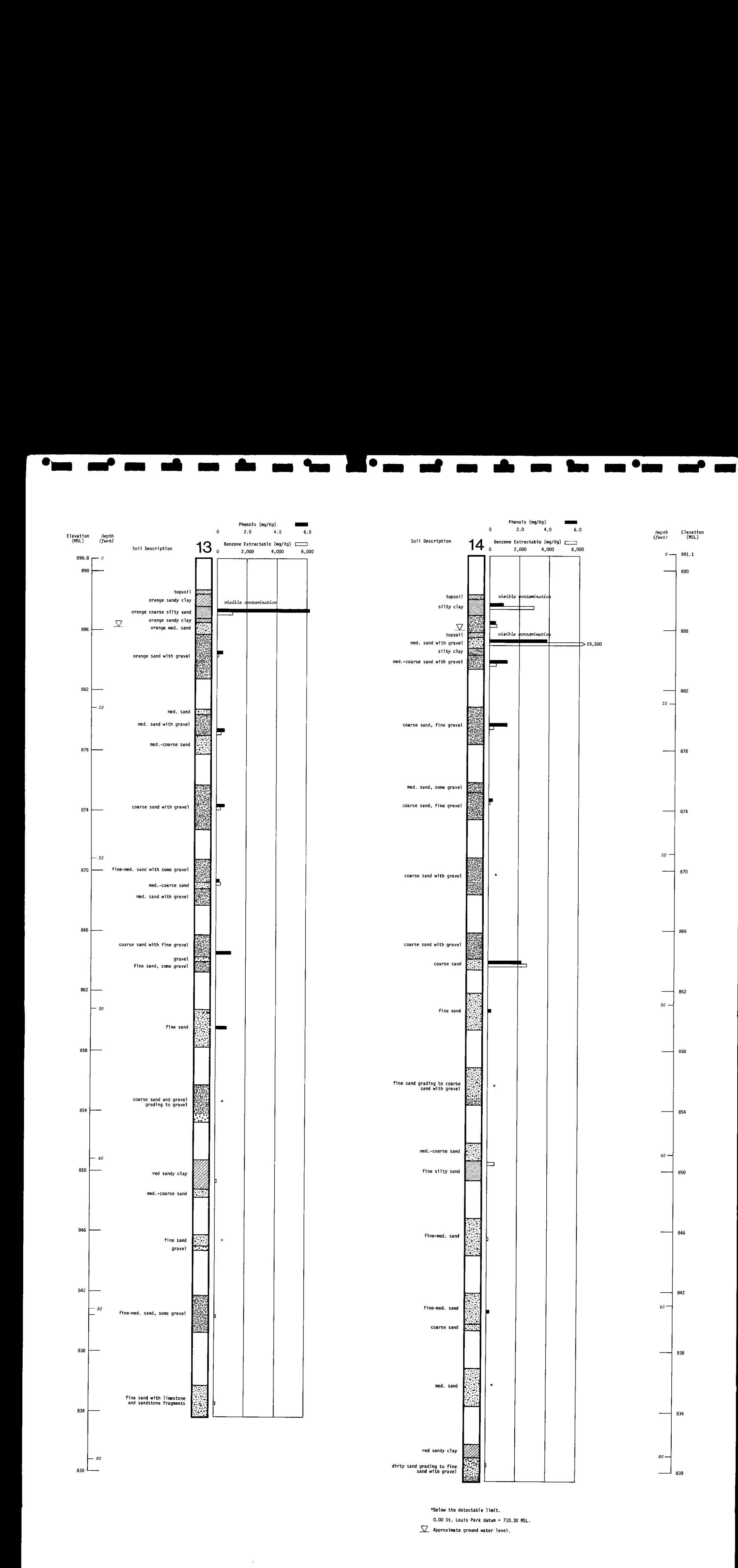
FIGURE 7

DISTRIBUTION OF PHENOLIC & BENZENE EXTRACTABLE MATERIAL

BORINGS 11 & 12



*Below the detectable limit.

0.00 St. Louis Park datum = 710.30 MSL.

▽ Approximate ground water level.

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SOIL AND GROUND WATER INVESTIGATION

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FIGURE 8

DISTRIBUTION OF PHENOLIC & BENZENE EXTRACTABLE MATERIAL

BORINGS 13 & 14

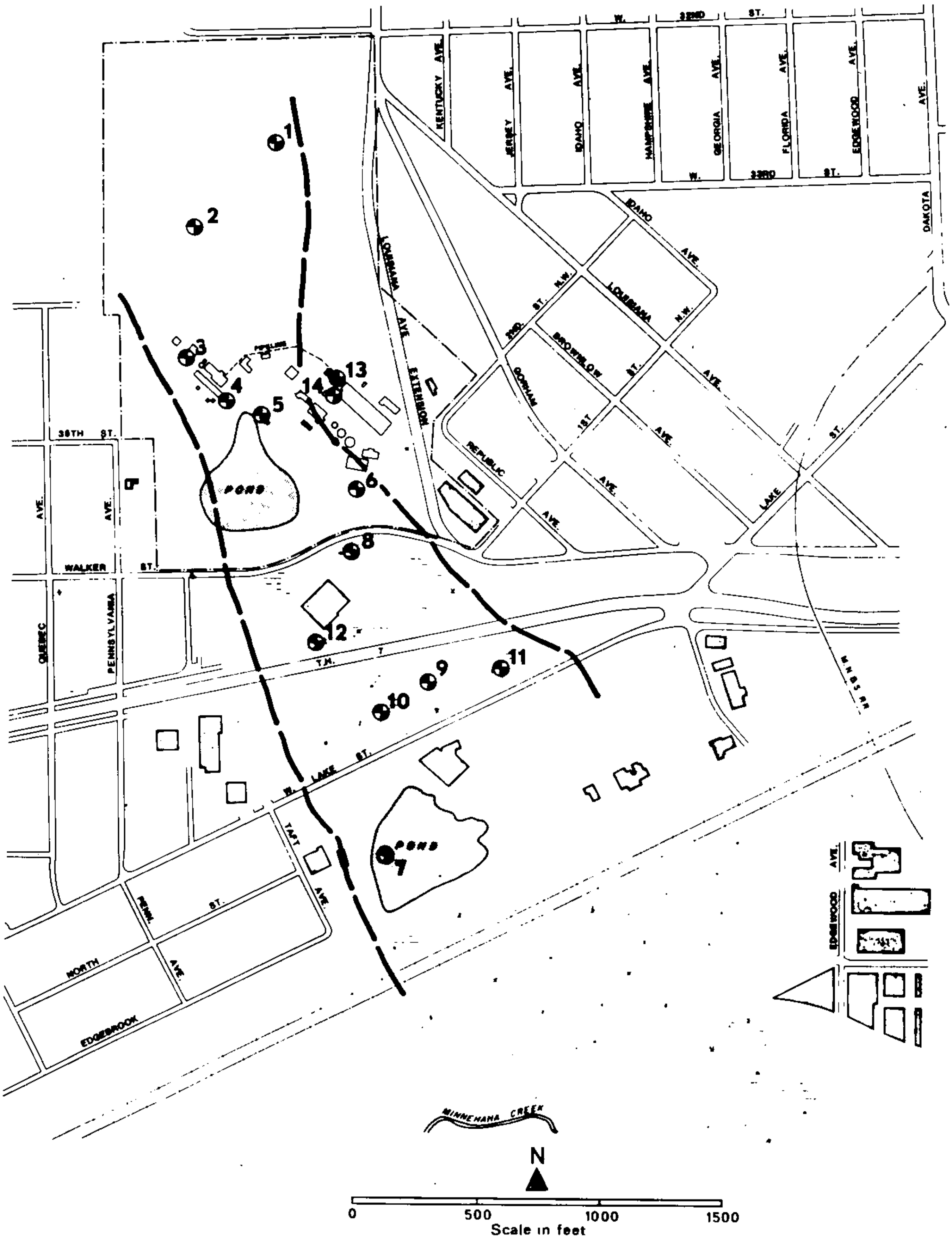


FIGURE 9

APPROXIMATE LIMITS OF LACUSTRINE DEPOSITS

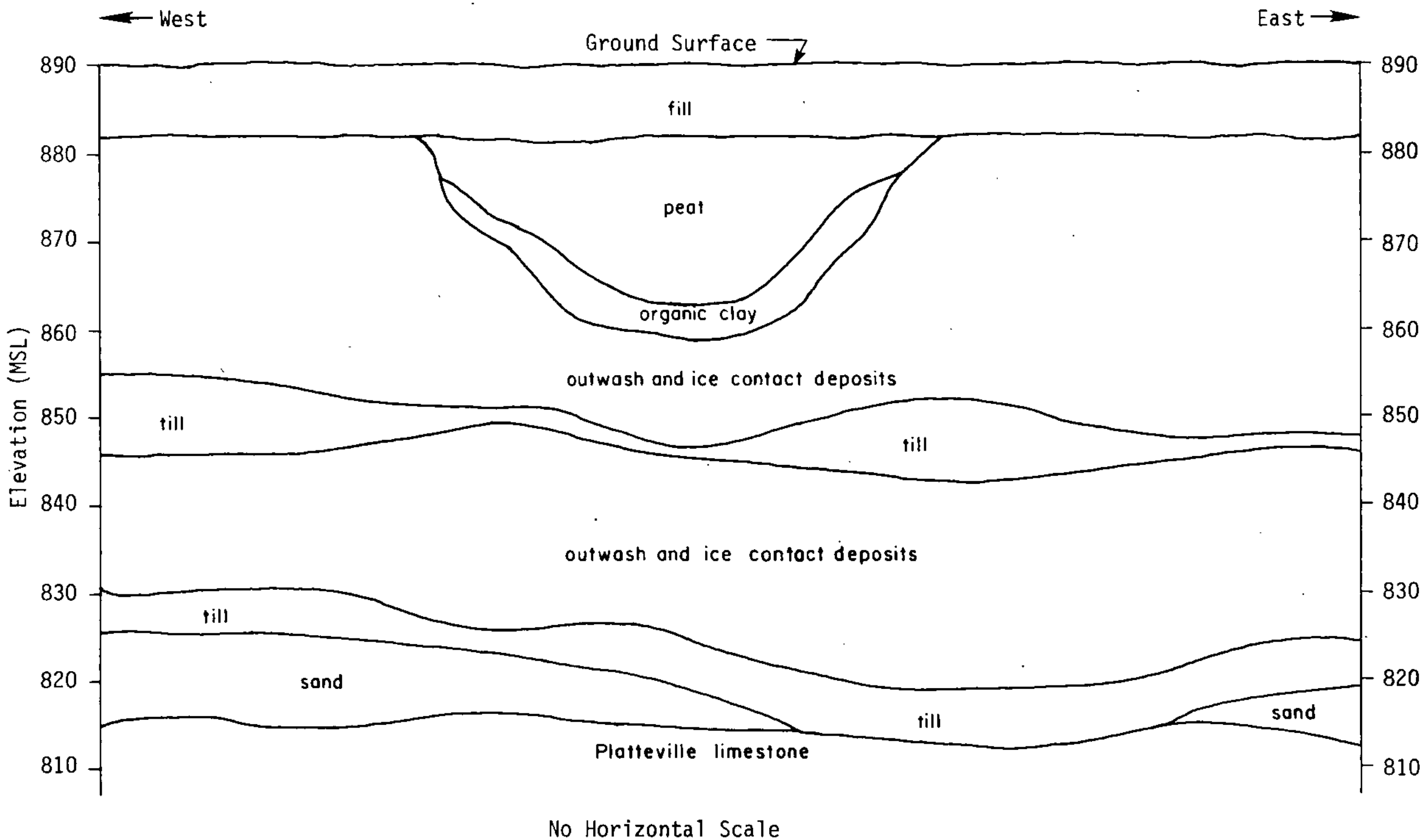


FIGURE 10

GENERALIZED GEOLOGIC SECTION OF GLACIAL STRATIGRAPHY THROUGH STUDY AREA

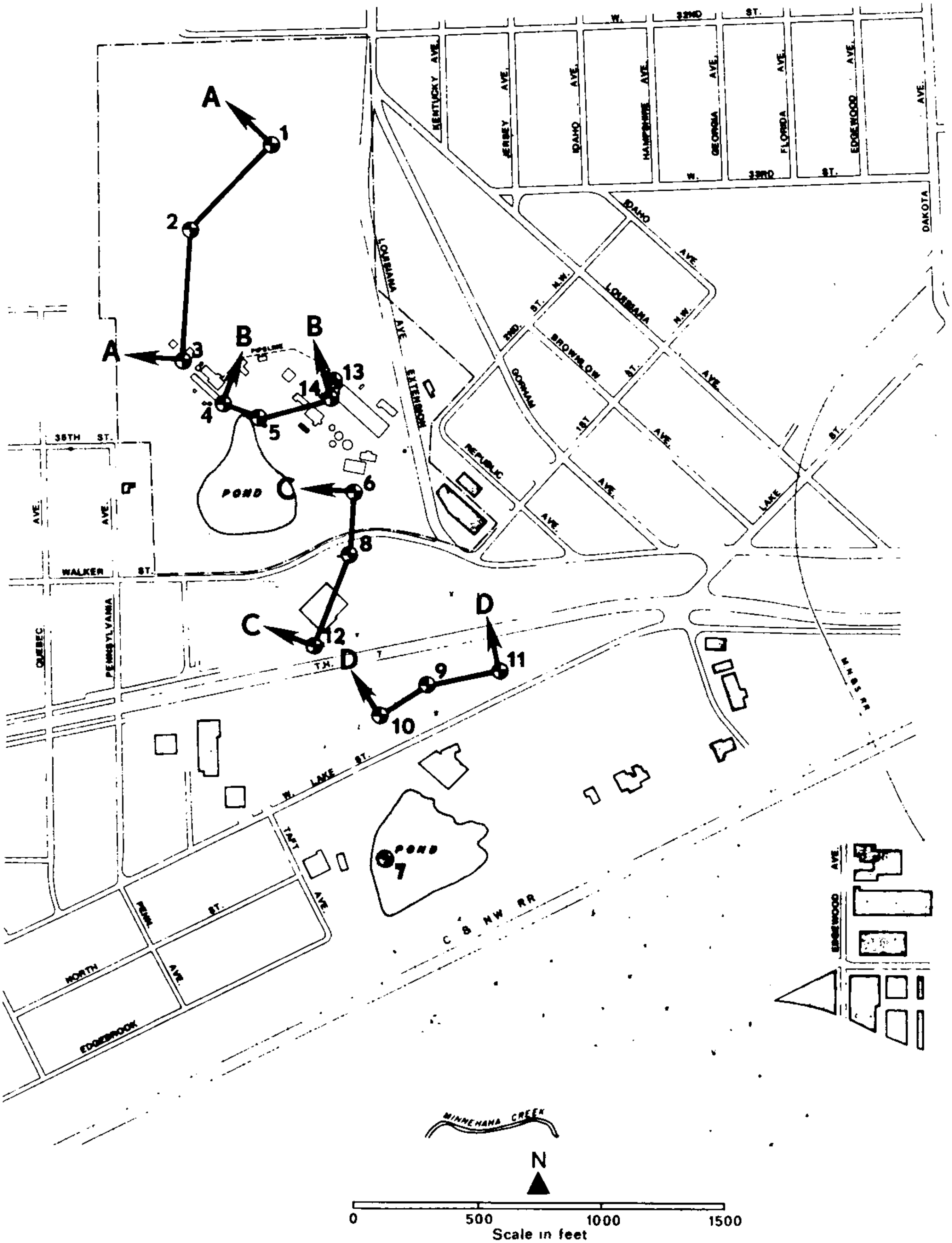


FIGURE 11

LOCATION OF GEOLOGIC SECTIONS A THROUGH D

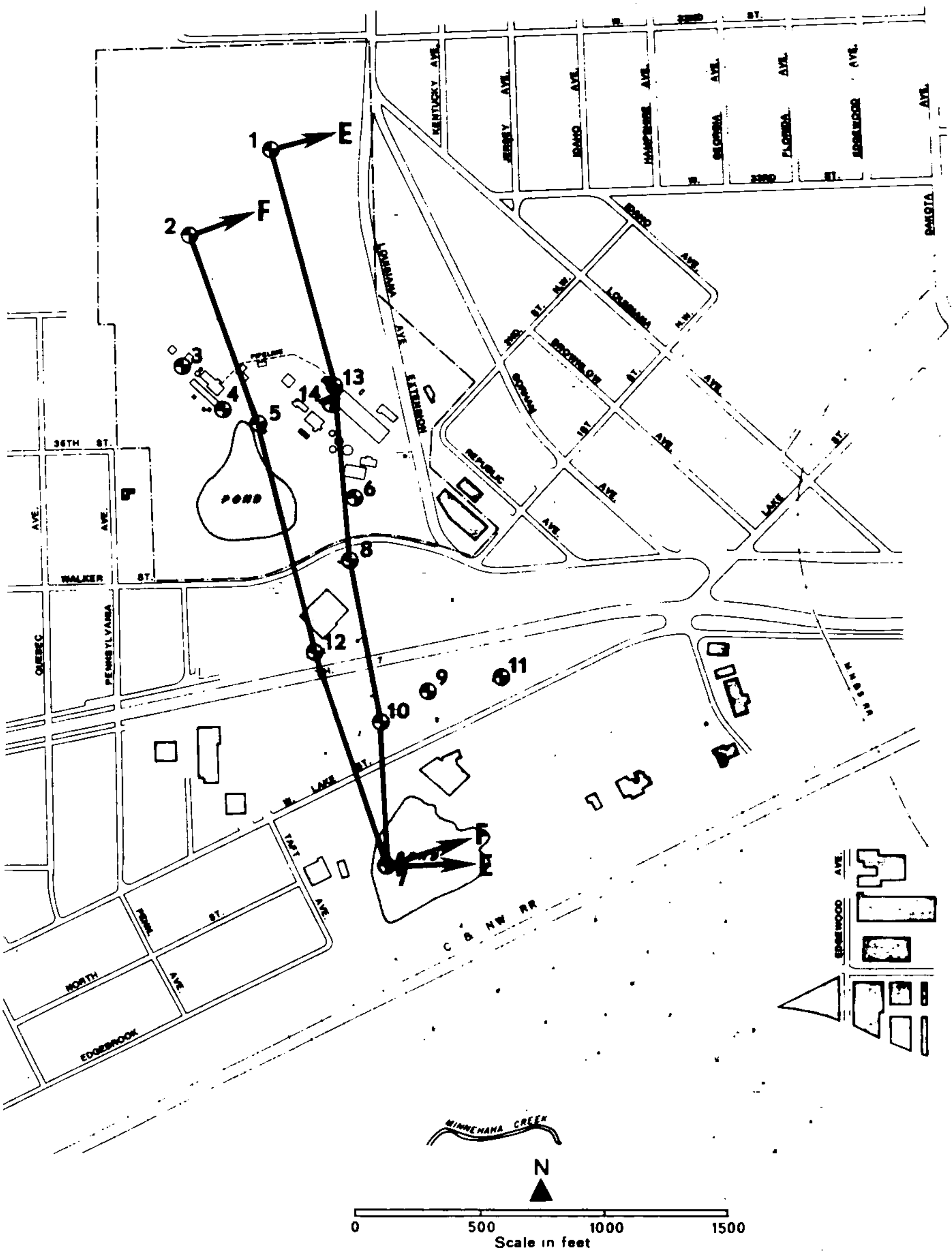


FIGURE 12

LOCATION OF GEOLOGIC SECTIONS E AND F

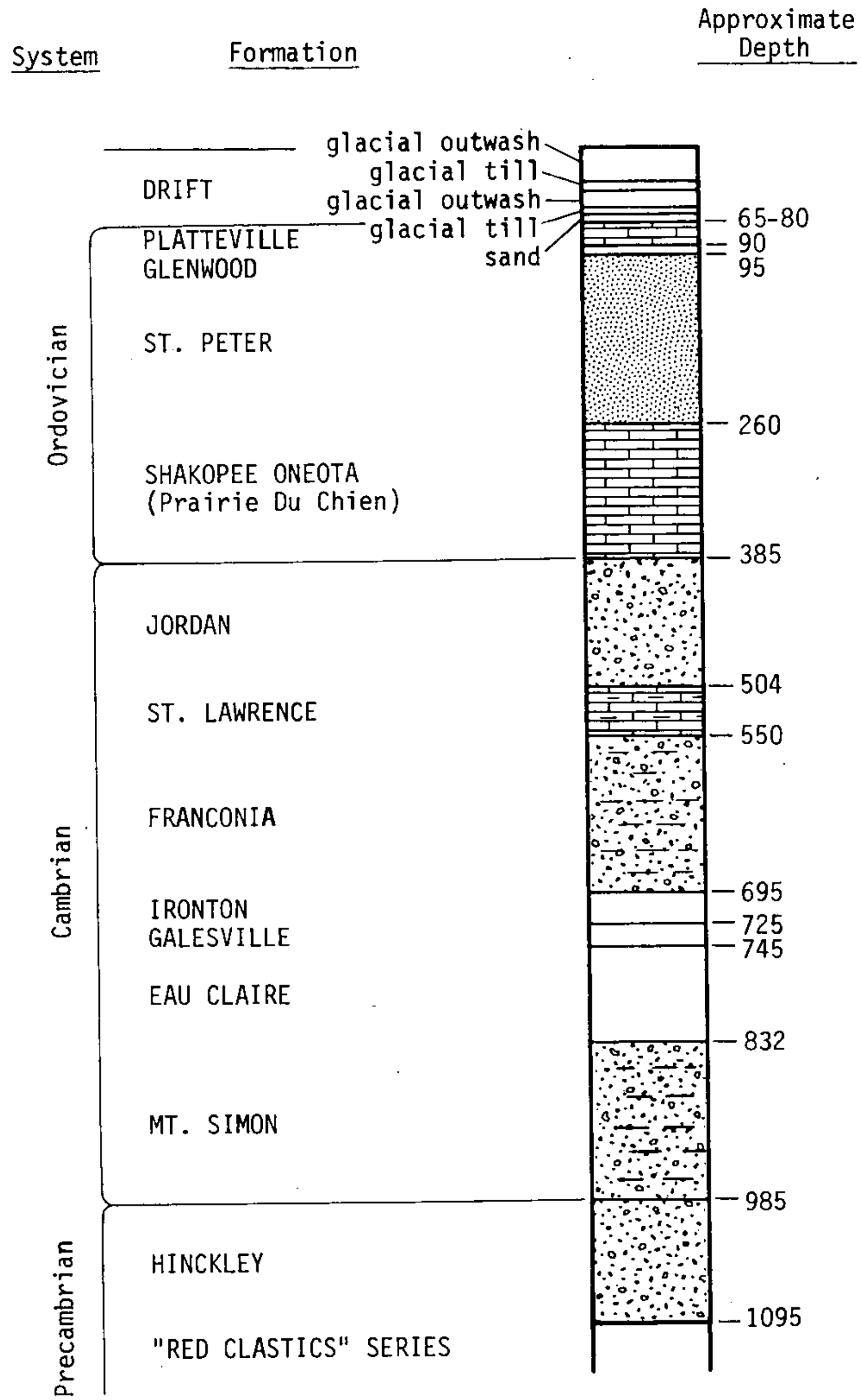


FIGURE 13

GENERALIZED GEOLOGIC COLUMN

Adopted from Sunde, Hydrogeologic Study
of the Republic Creosote Site (1974).

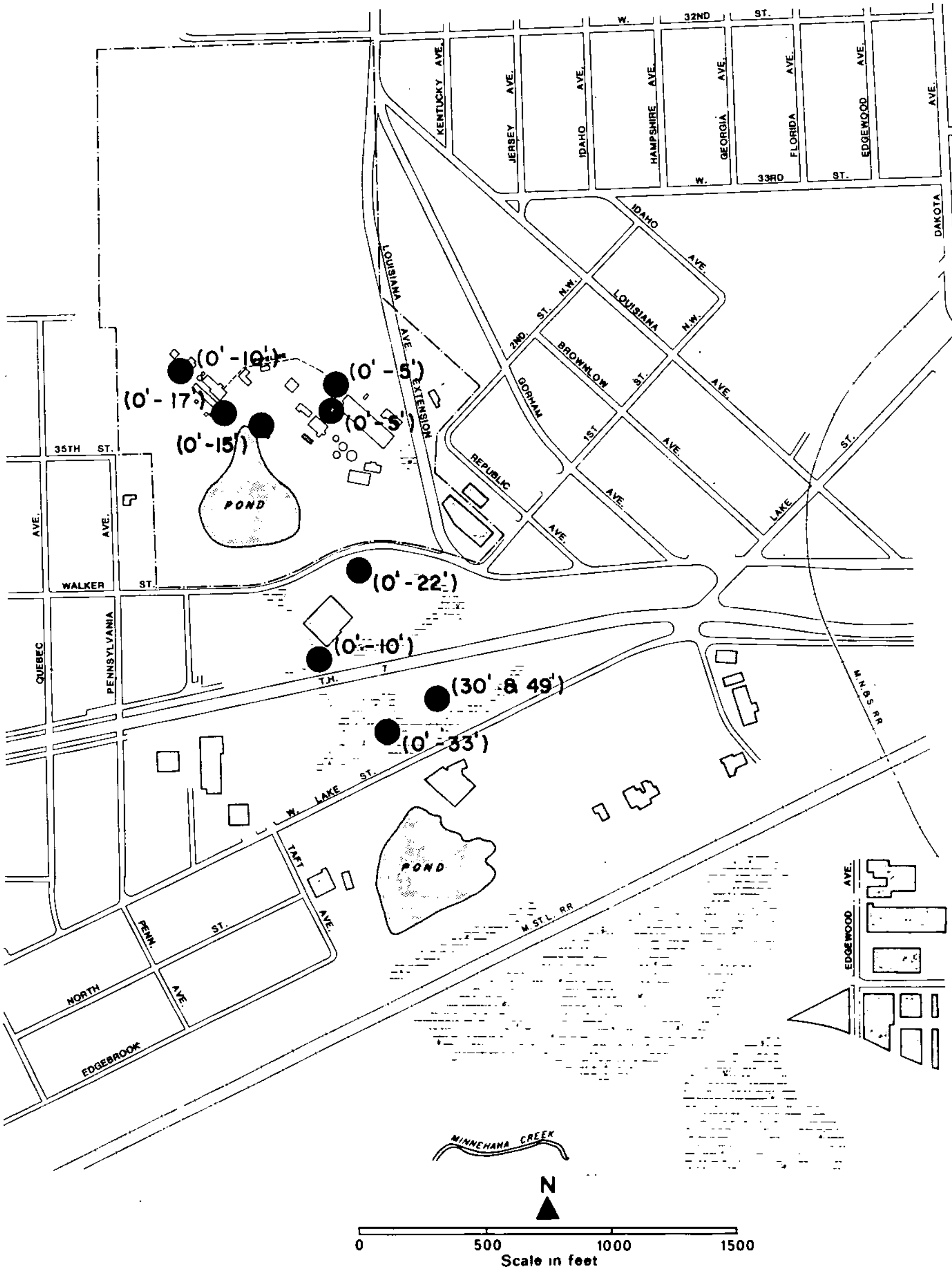


FIGURE 14

LOCATION OF VISIBLY CONTAMINATED SOIL SAMPLES

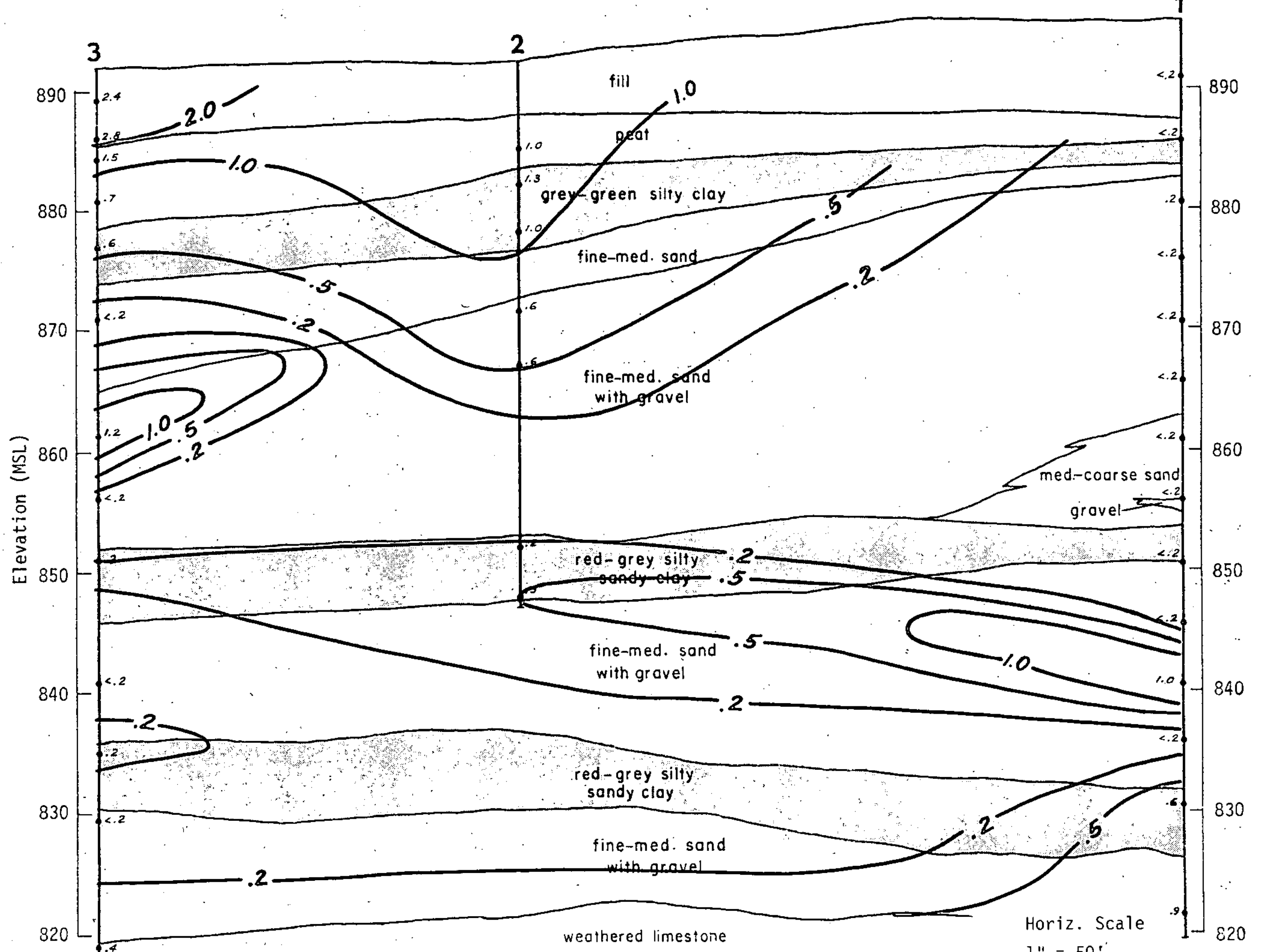
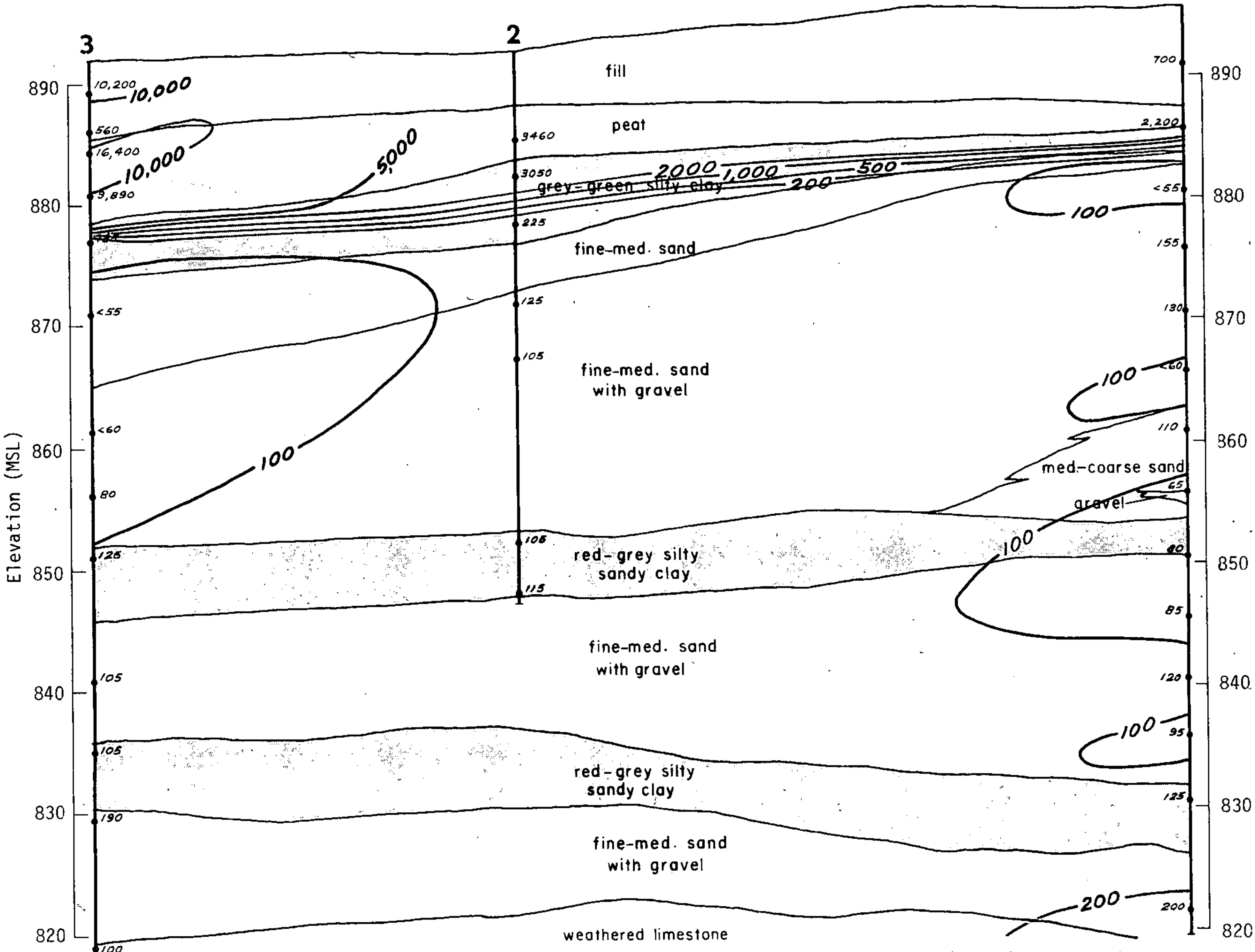


FIGURE 15 - GEOLOGIC SECTION A - PHENOLIC LEVELS (mg/Kg)



Horiz. Scale 1"=50'

FIGURE 16 GEOLOGIC SECTION A - BENZENE EXTRACTABLE LEVELS (mg/kg)

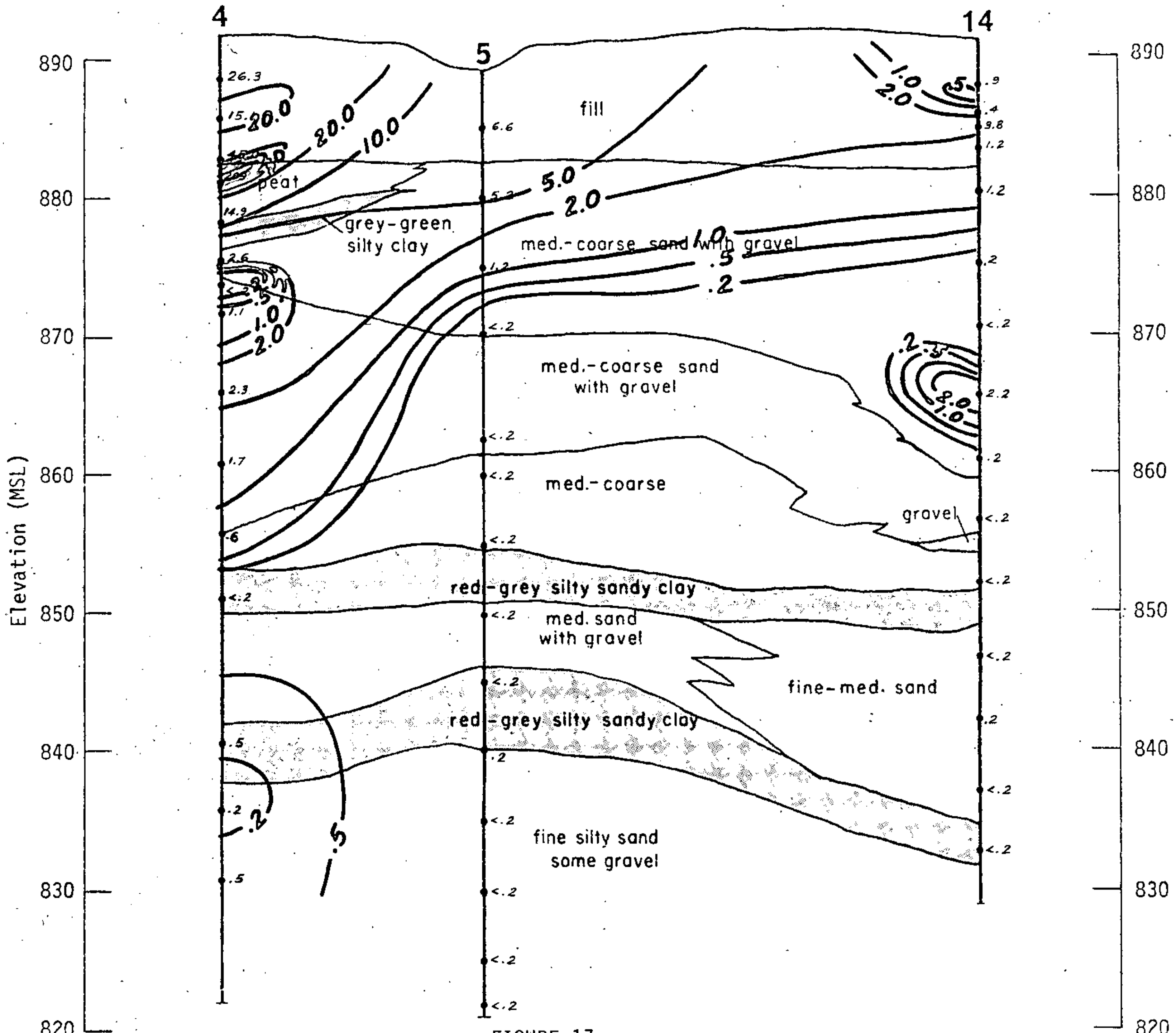


FIGURE 17
GEOLOGIC SECTION B - PHENOLIC LEVELS (mg/Kg)

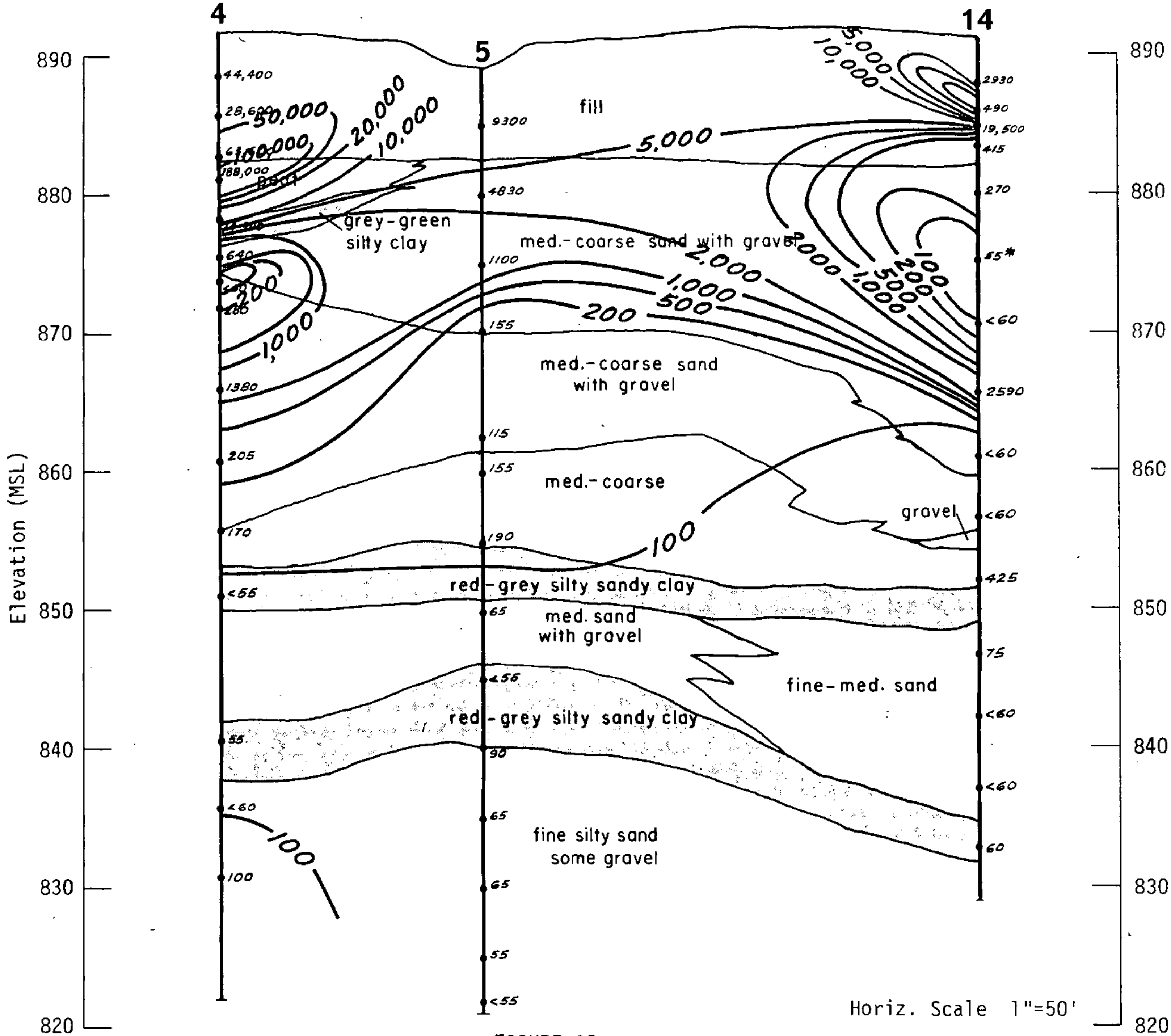
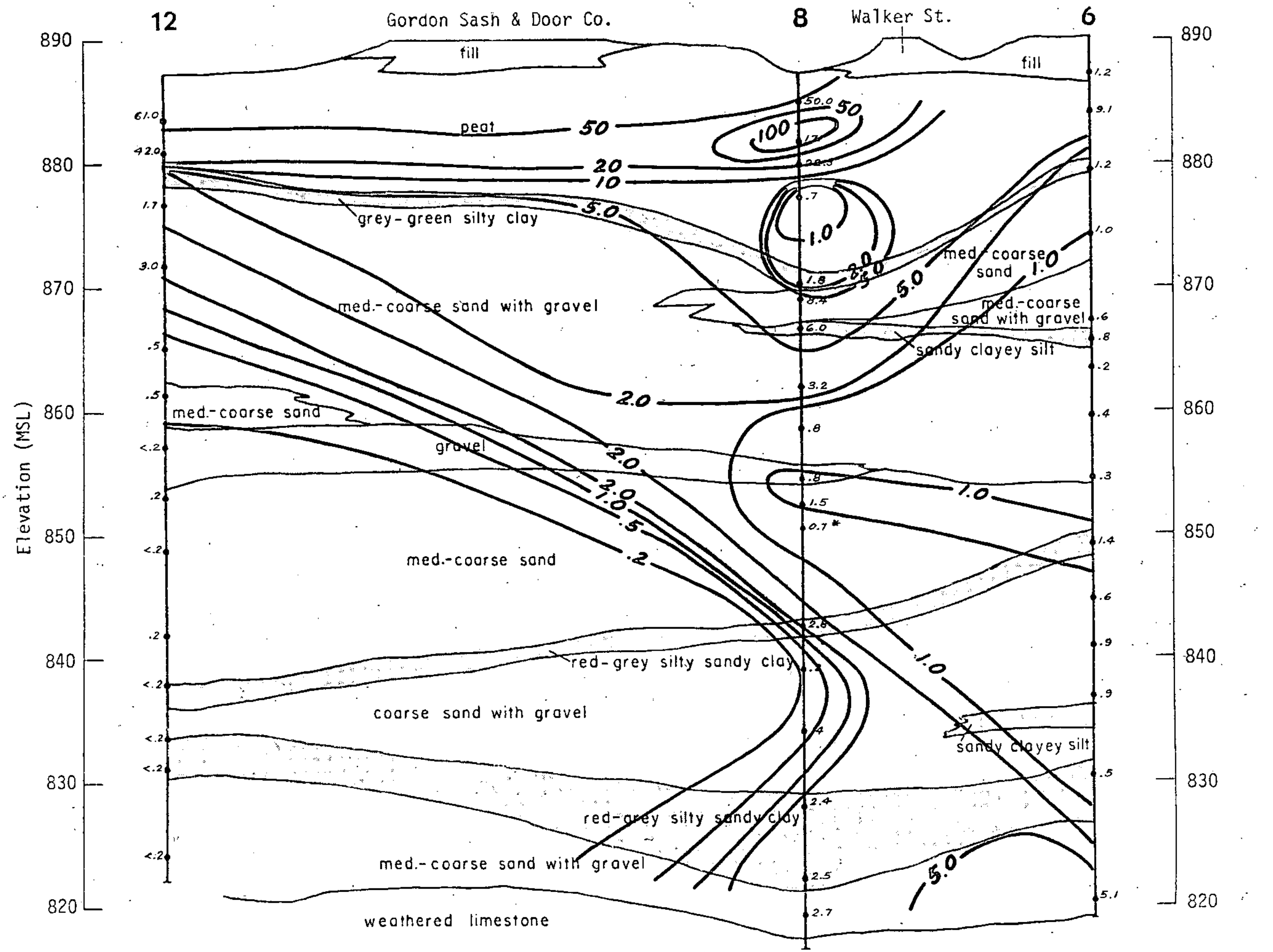
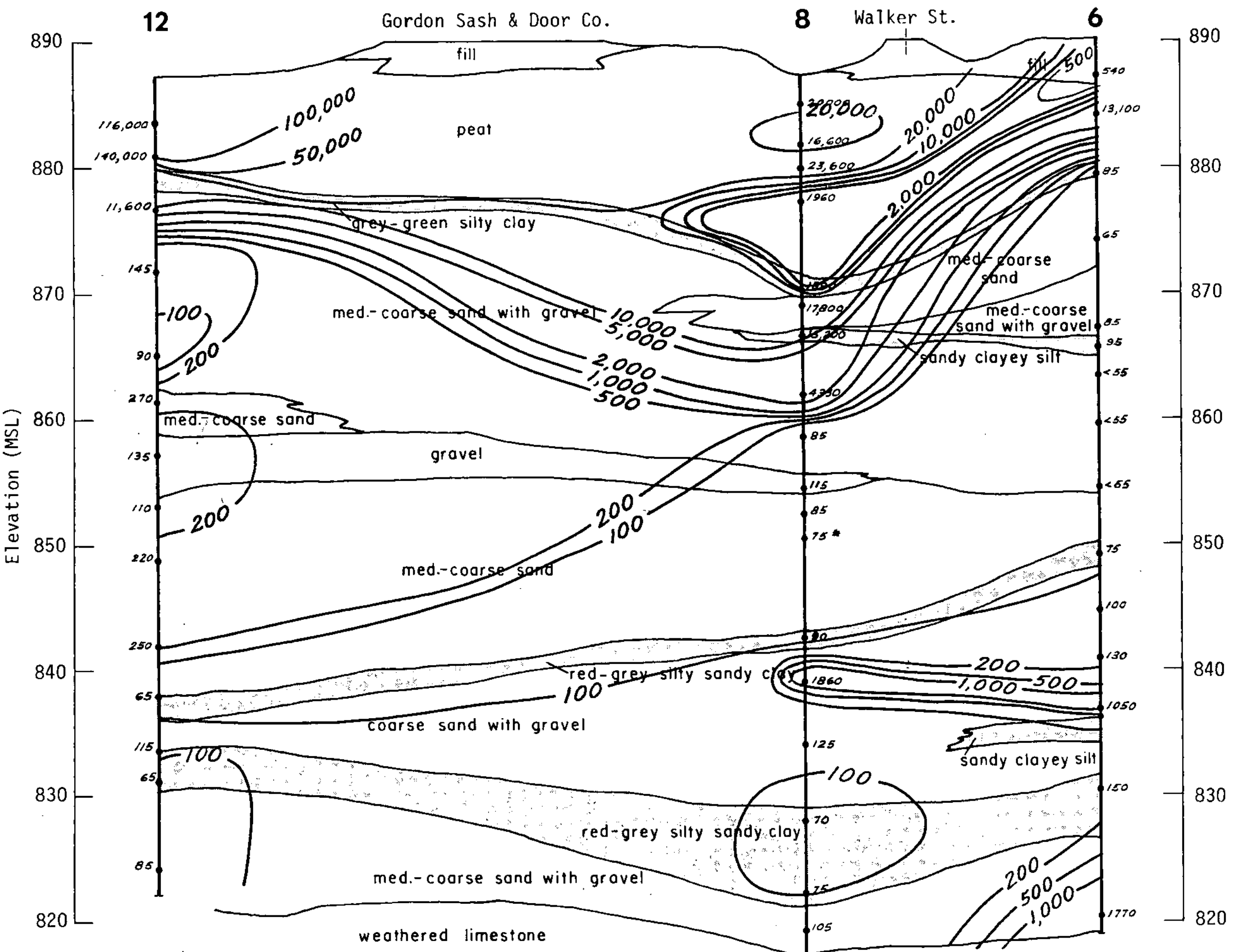


FIGURE 18
GEOLOGIC SECTION B - BENZENE EXTRACTABLE LEVELS (mg/Kg)



Horiz. Scale 1"=50'

FIGURE 19 - GEOLOGIC SECTION C - PHENOLIC LEVELS (mg/Kg)



Horiz. Scale 1"=50'

FIGURE 20 - GEOLOGIC SECTION C - BENZENE EXTRACTABLE LEVELS (mg/Kg)

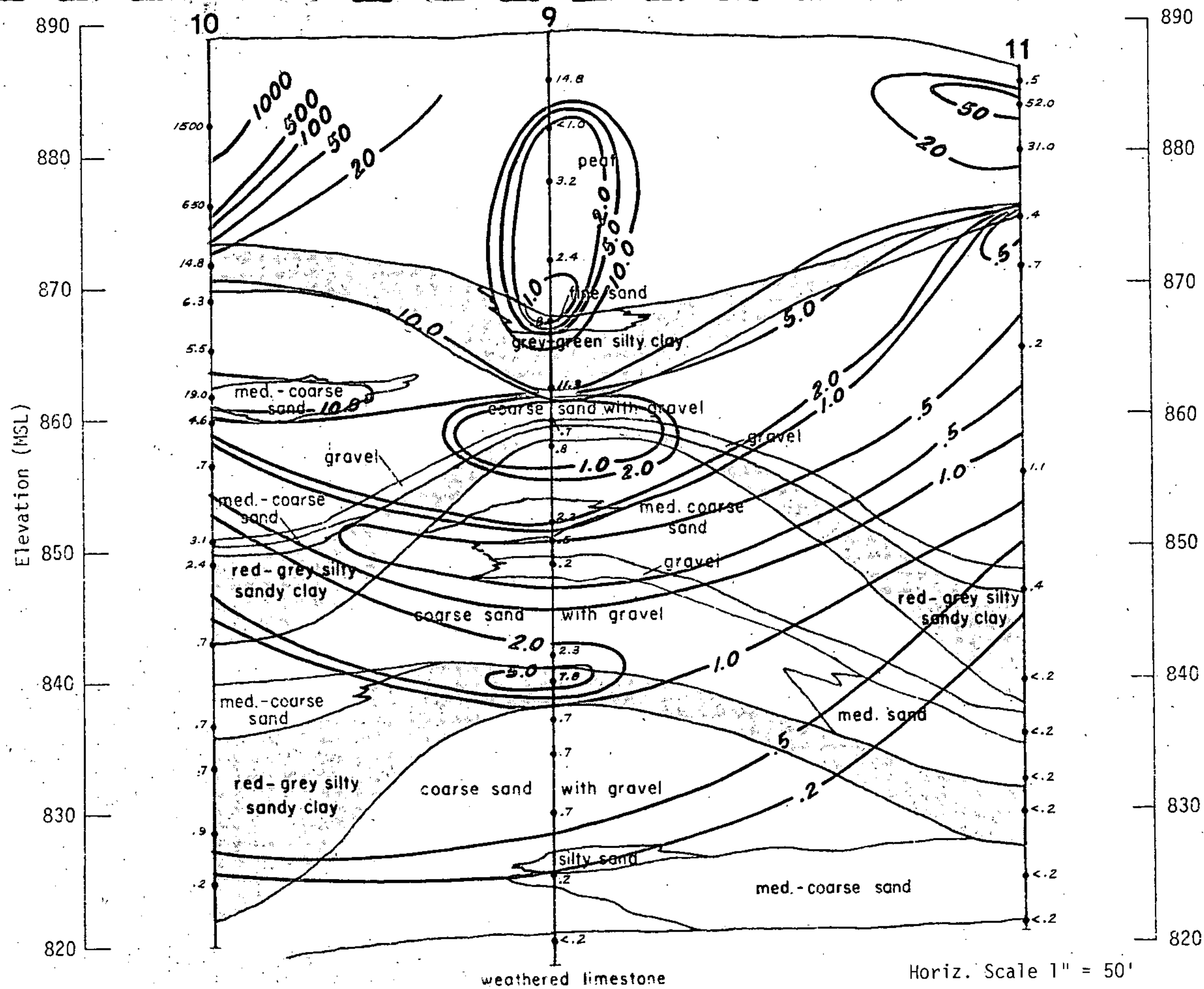


FIGURE 21
GEOLOGIC SECTION D - PHENOLIC LEVELS (mg/Kg)

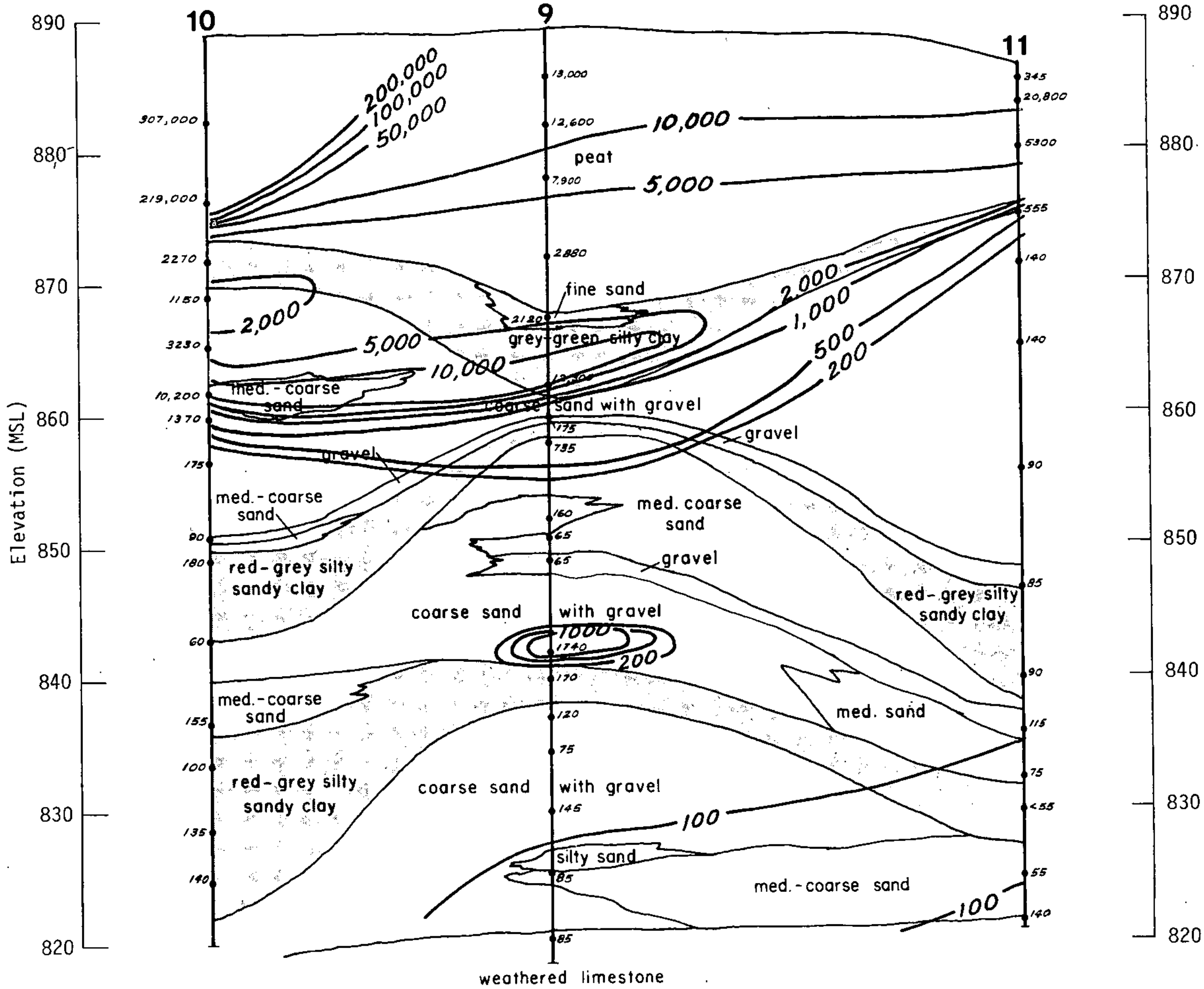


FIGURE 22

GEOLOGIC SECTION D - BENEZENE EXTRACTABLE LEVELS (mg/Kg)

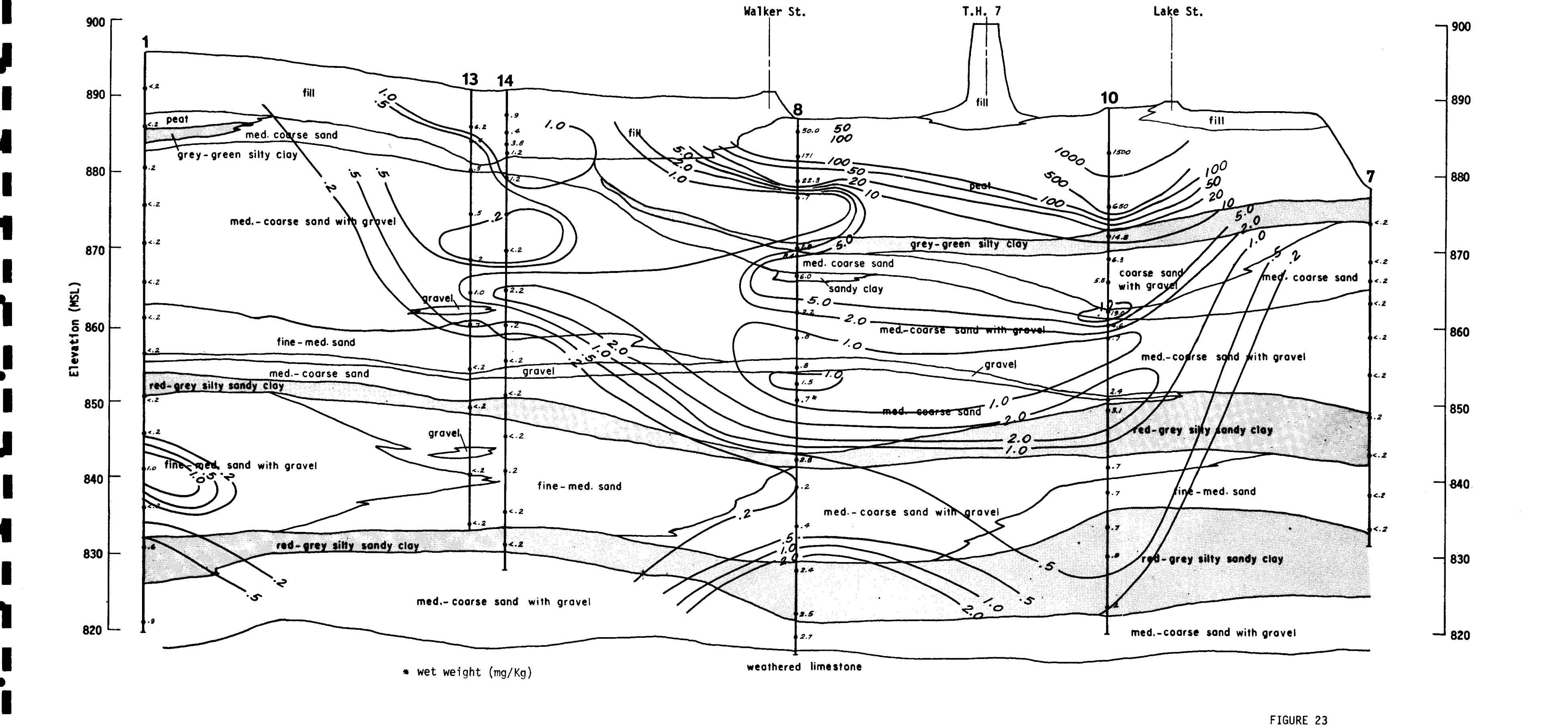


FIGURE 23
GEOLOGIC SECTION - PHENOLIC LEVELS (mg/kg)

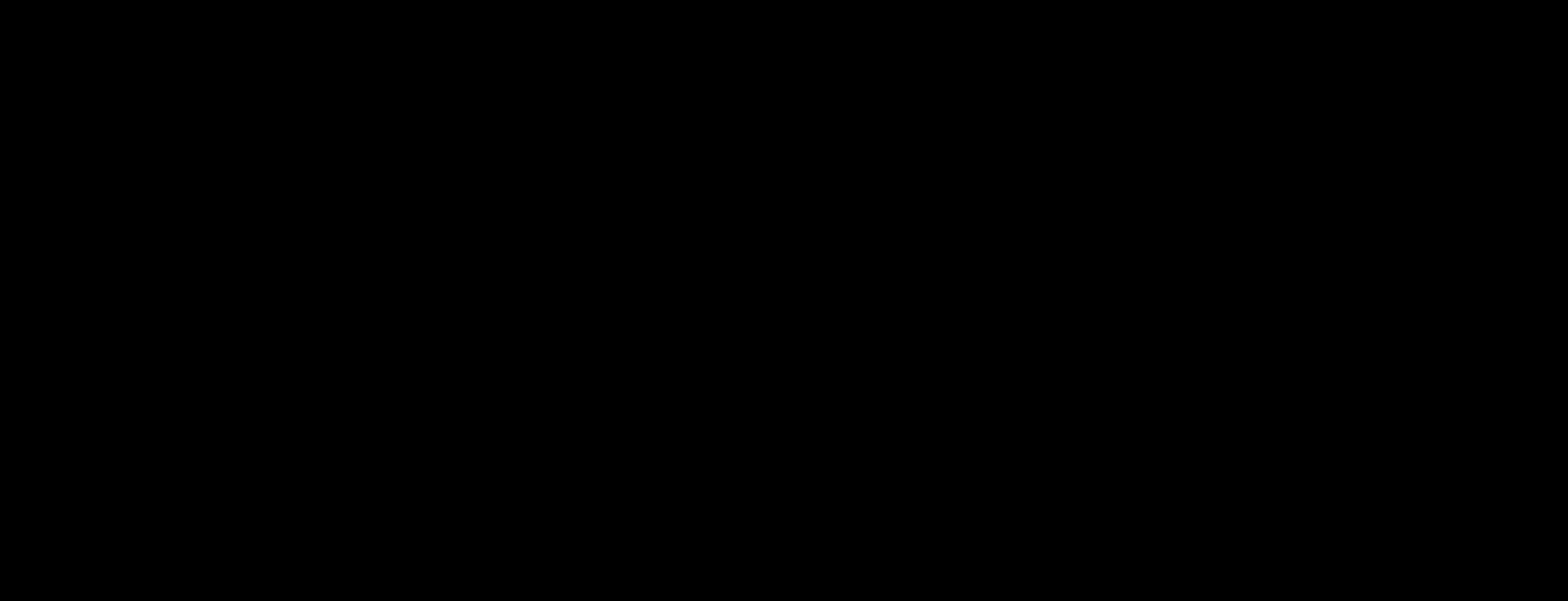
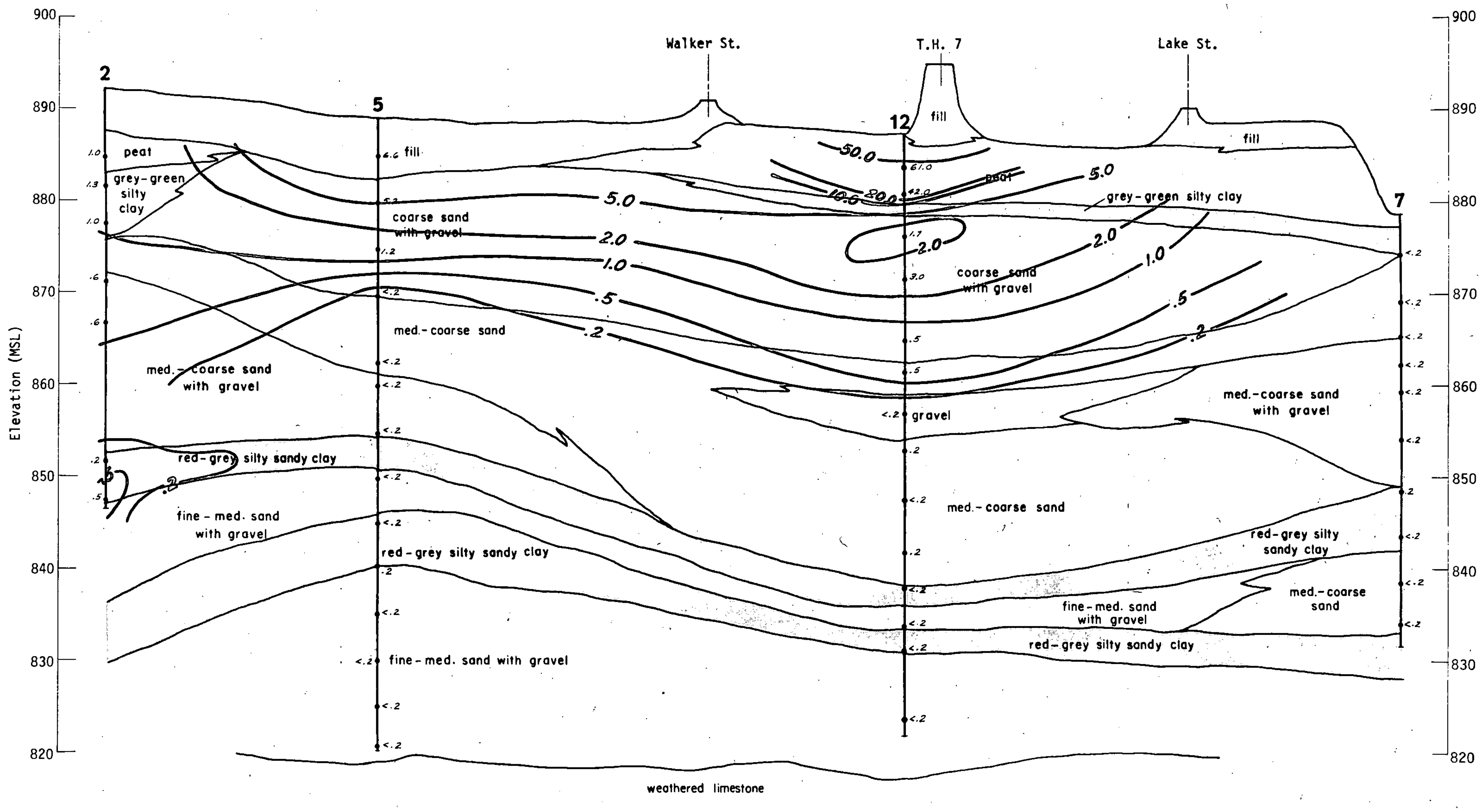


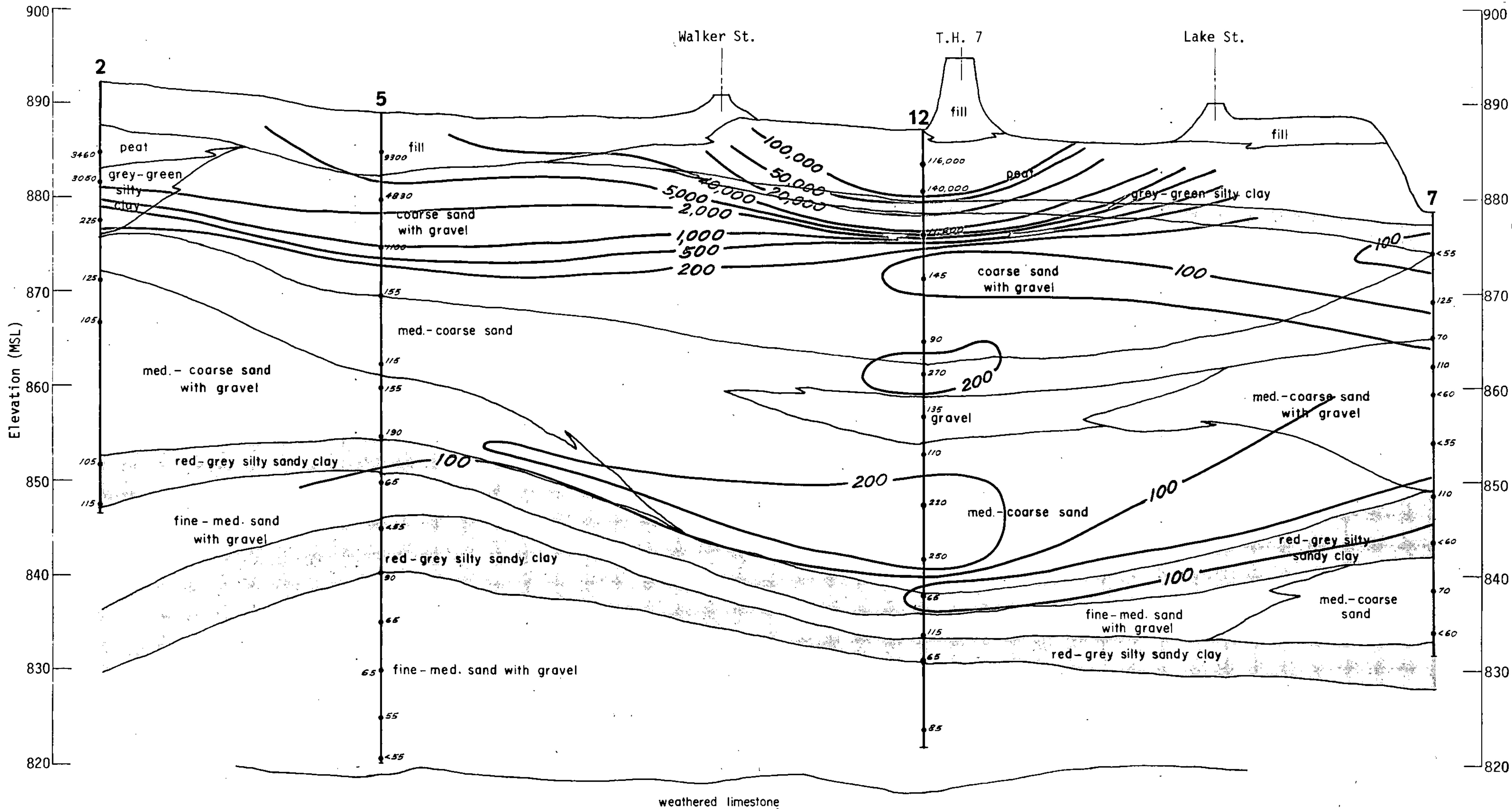
FIGURE 24
GEOLOGIC SECTION E - BENZENE EXTRACTABLE LEVELS (mg/kg)



Horizontal Scale 1" = 100'

FIGURE 25

GEOLOGIC SECTION F - PHENOLIC LEVELS (mg/kg)



Horizontal Scale 1" = 100'

FIGURE 26

GEOLOGIC SECTION F - BENZENE EXTRACTABLE LEVELS (mg/Kg)

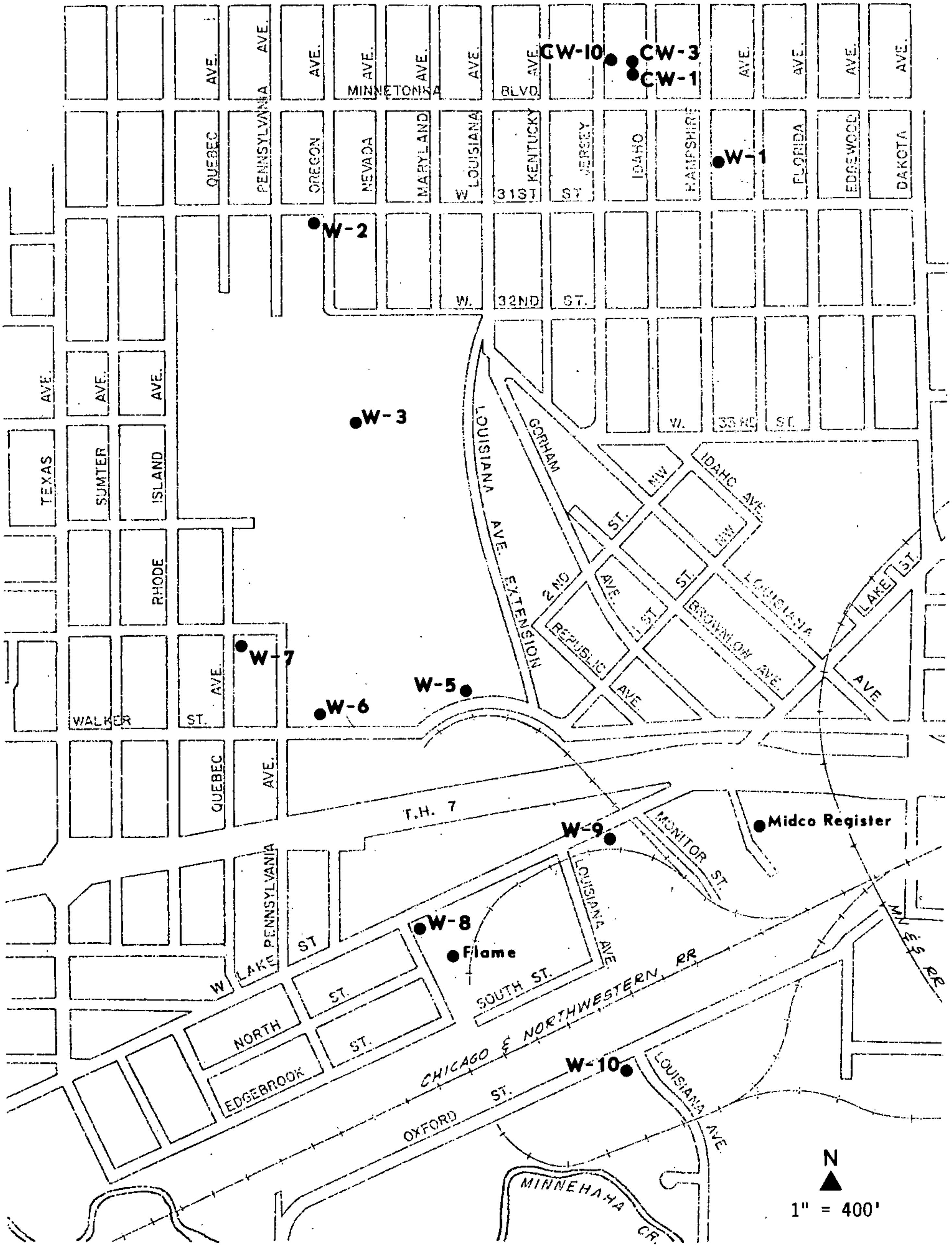


FIGURE 27
LOCATION OF PHASE I GROUND WATER MONITORING WELLS

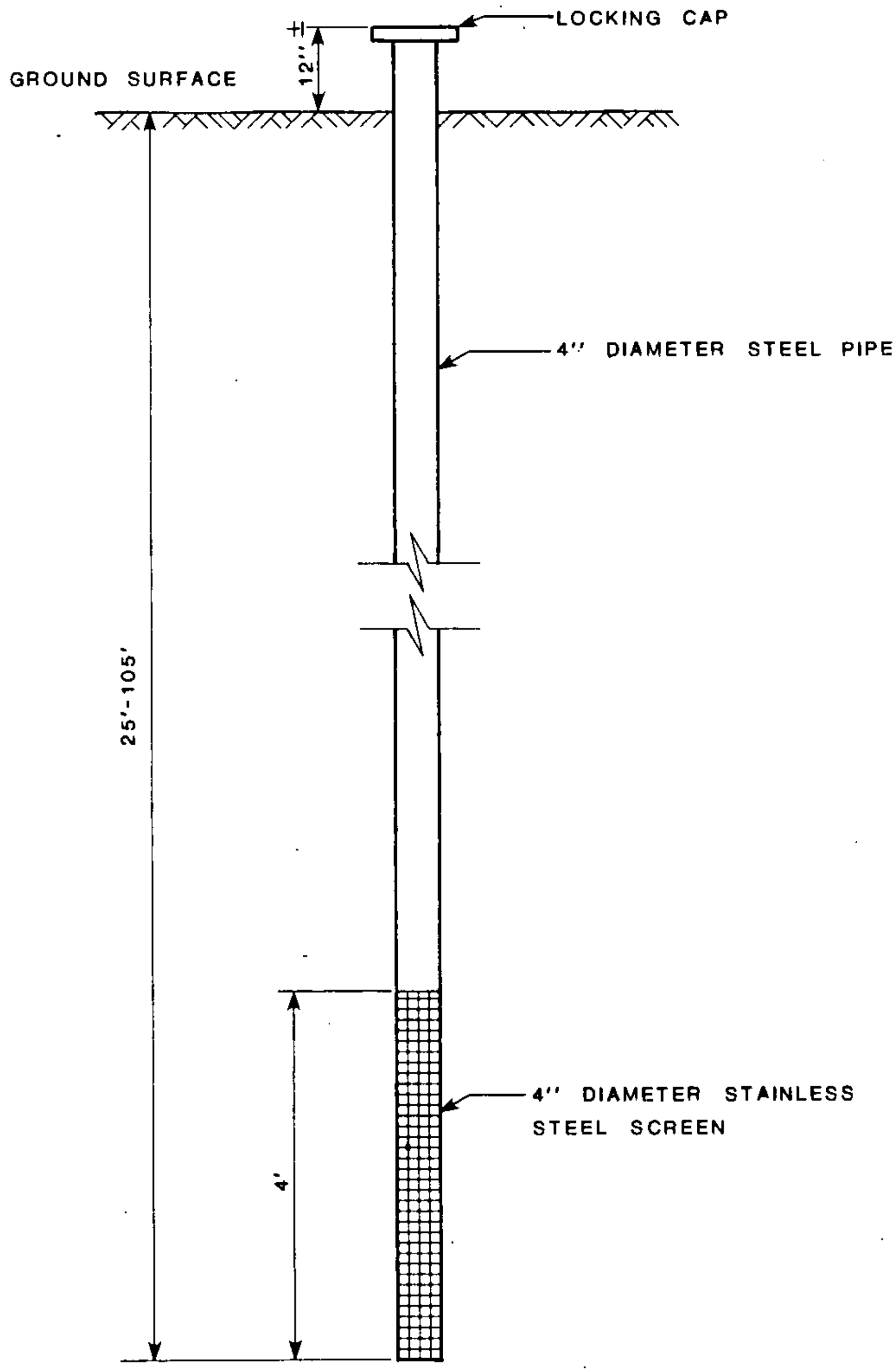


FIGURE 28

SECTION THROUGH TYPICAL PHASE I MONITORING WELL

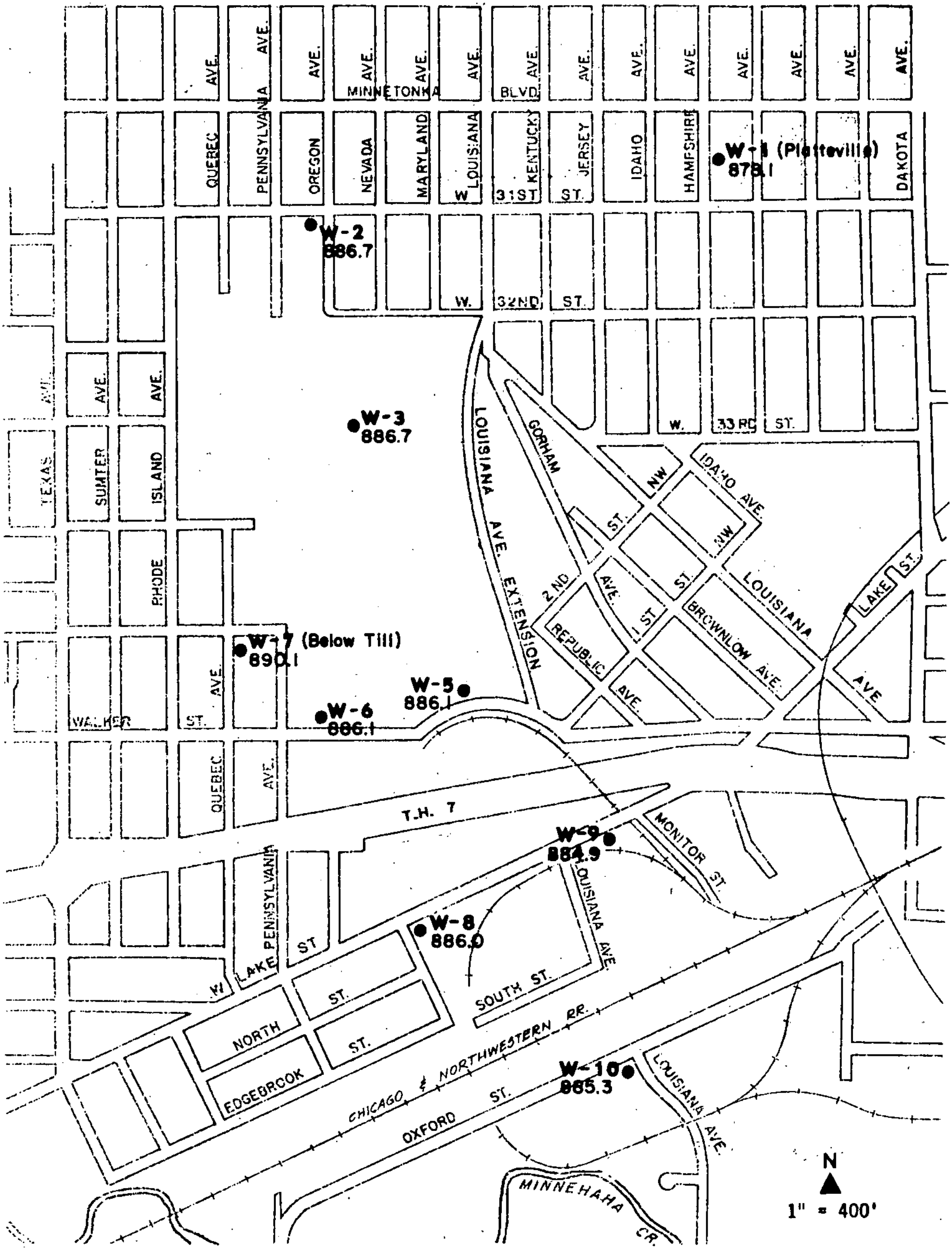


FIGURE 29
GROUND WATER LEVELS - MARCH 25, 1976

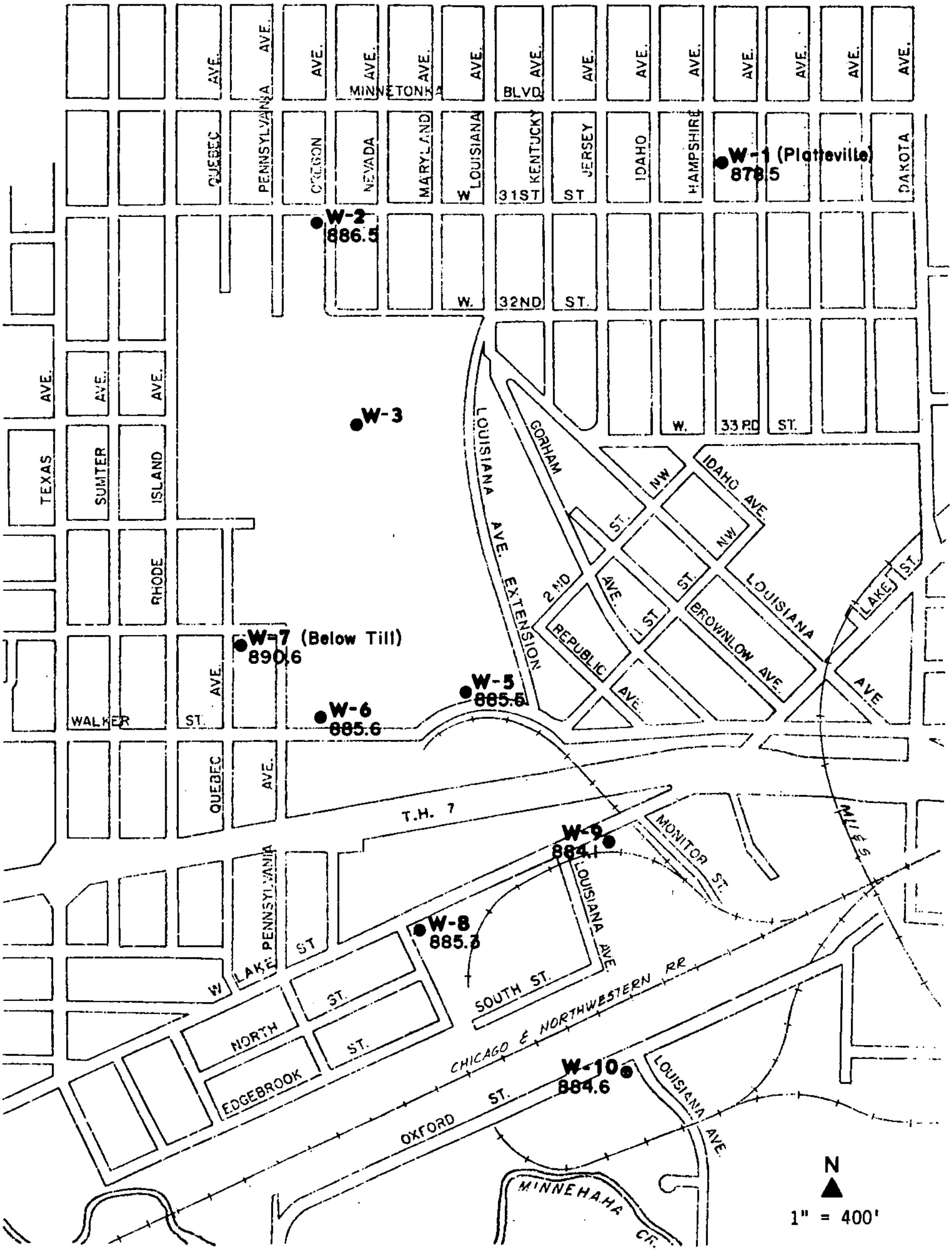
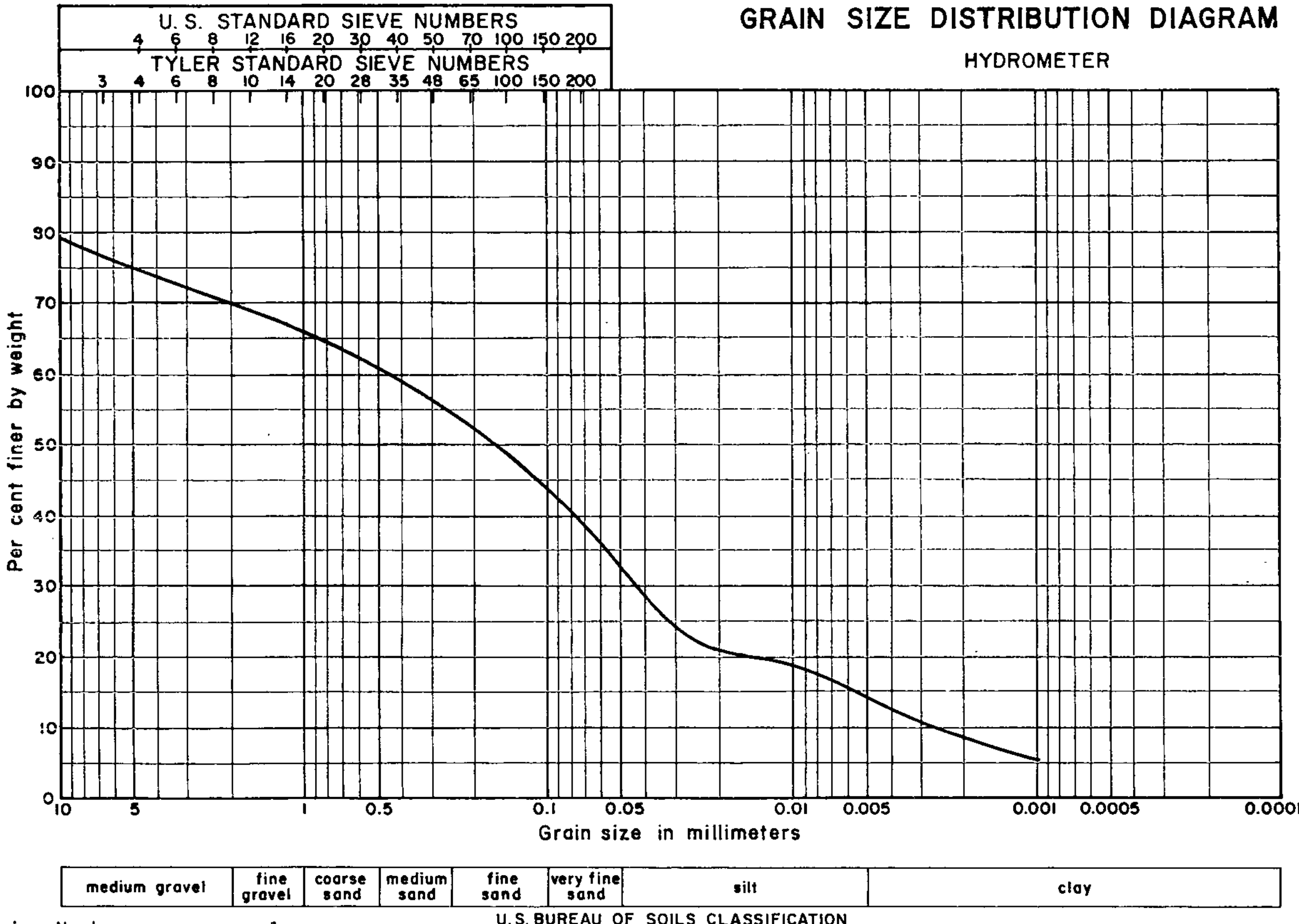


FIGURE 30

GROUND WATER LEVELS - MAY 6, 1976

GRAIN SIZE DISTRIBUTION DIAGRAM

HYDROMETER



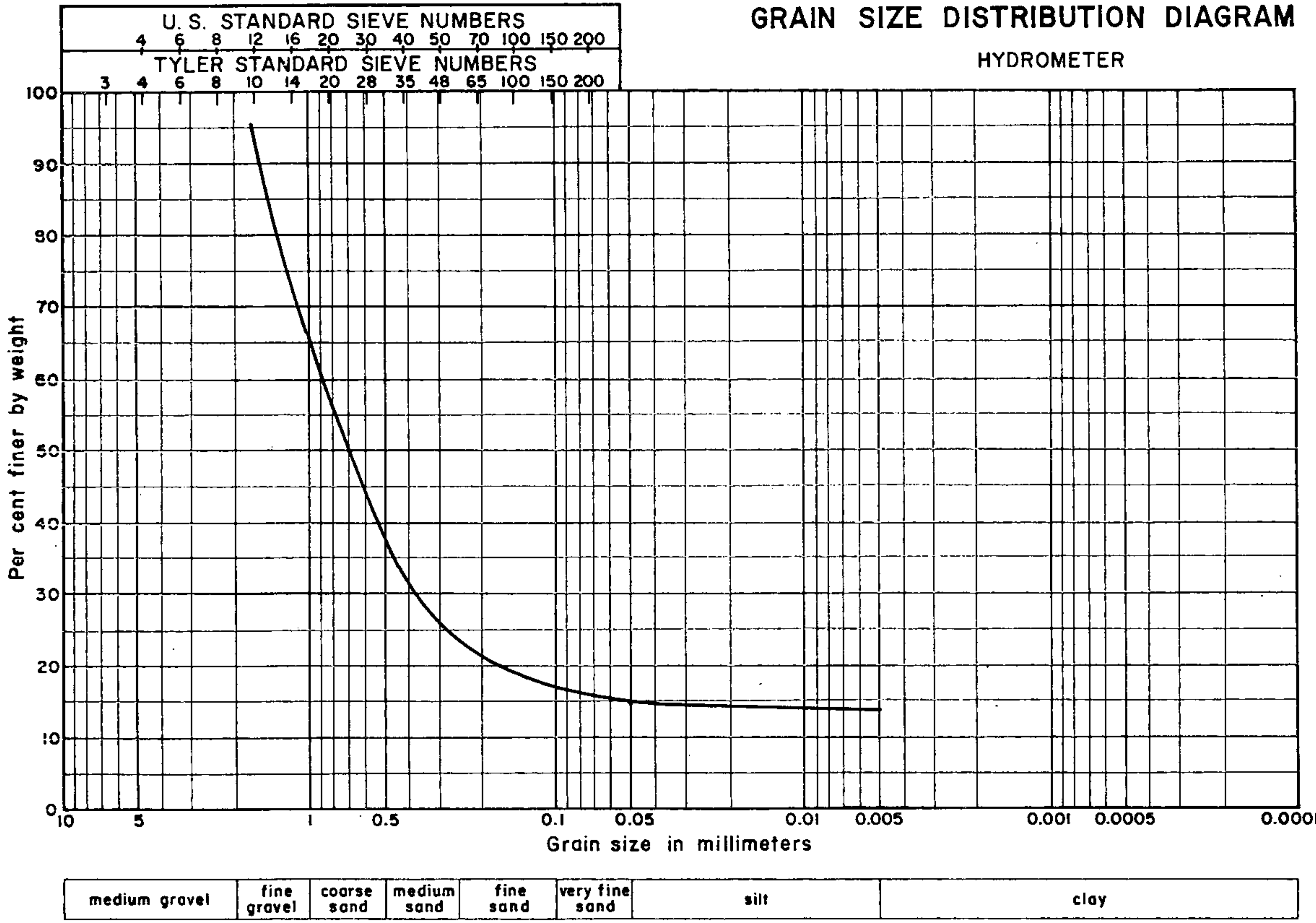
Boring Number: 1
Depth: 54 to 56 feet
Visual Classification: red silty sandy clay till
Estimated Permeability: 5×10^{-6} cm/sec.

FIGURE 31

BARR ENGINEERING CO.
Minneapolis, Minnesota

GRAIN SIZE DISTRIBUTION DIAGRAM

HYDROMETER



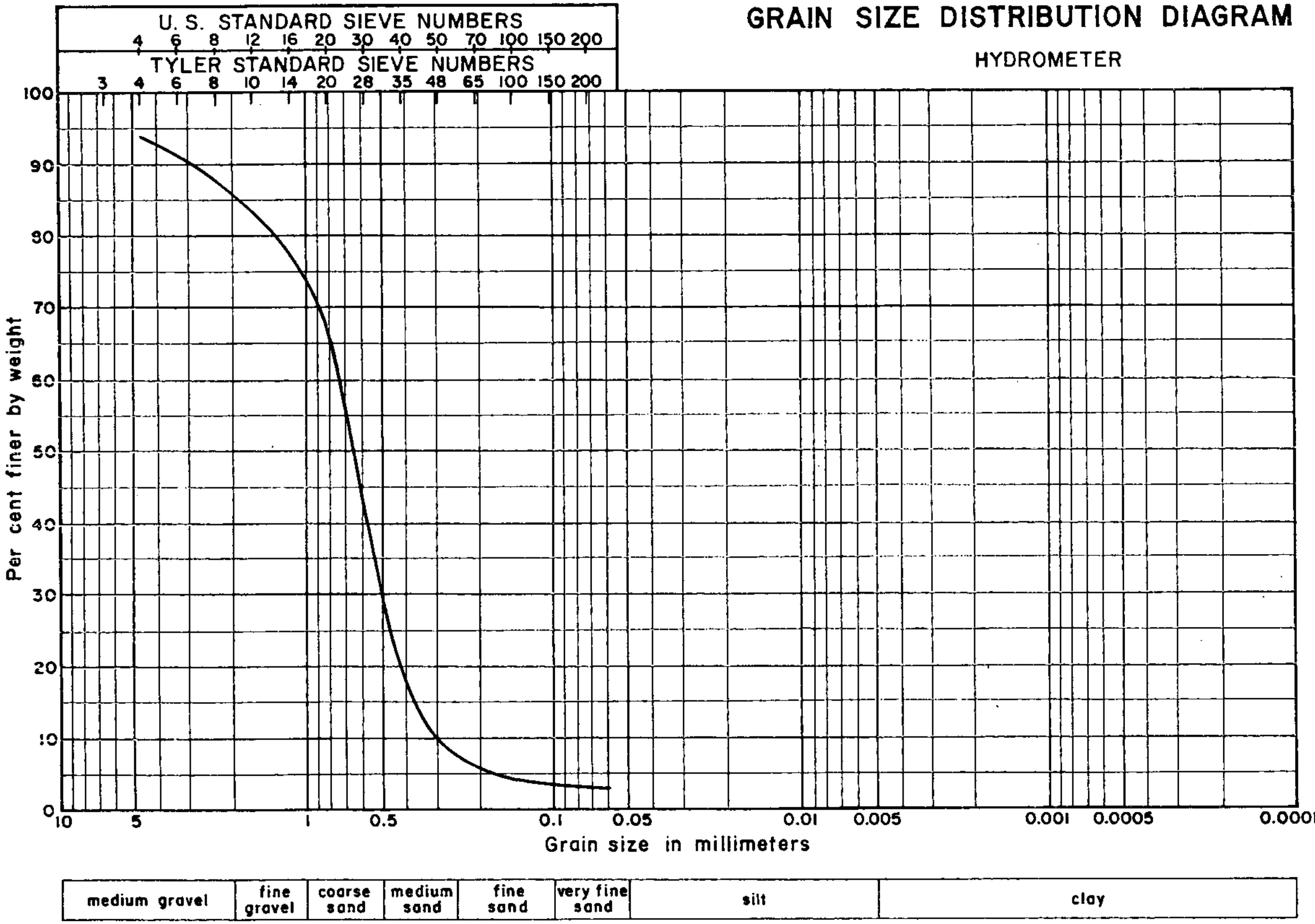
U.S. BUREAU OF SOILS CLASSIFICATION

Boring Number: 9
Depth: 25 to 28 feet
Visual Classification: green-grey clay
Estimated Permeability: 1 x 10^{-5} cm/sec.

FIGURE 32

BARR ENGINEERING CO.
Minneapolis, Minnesota

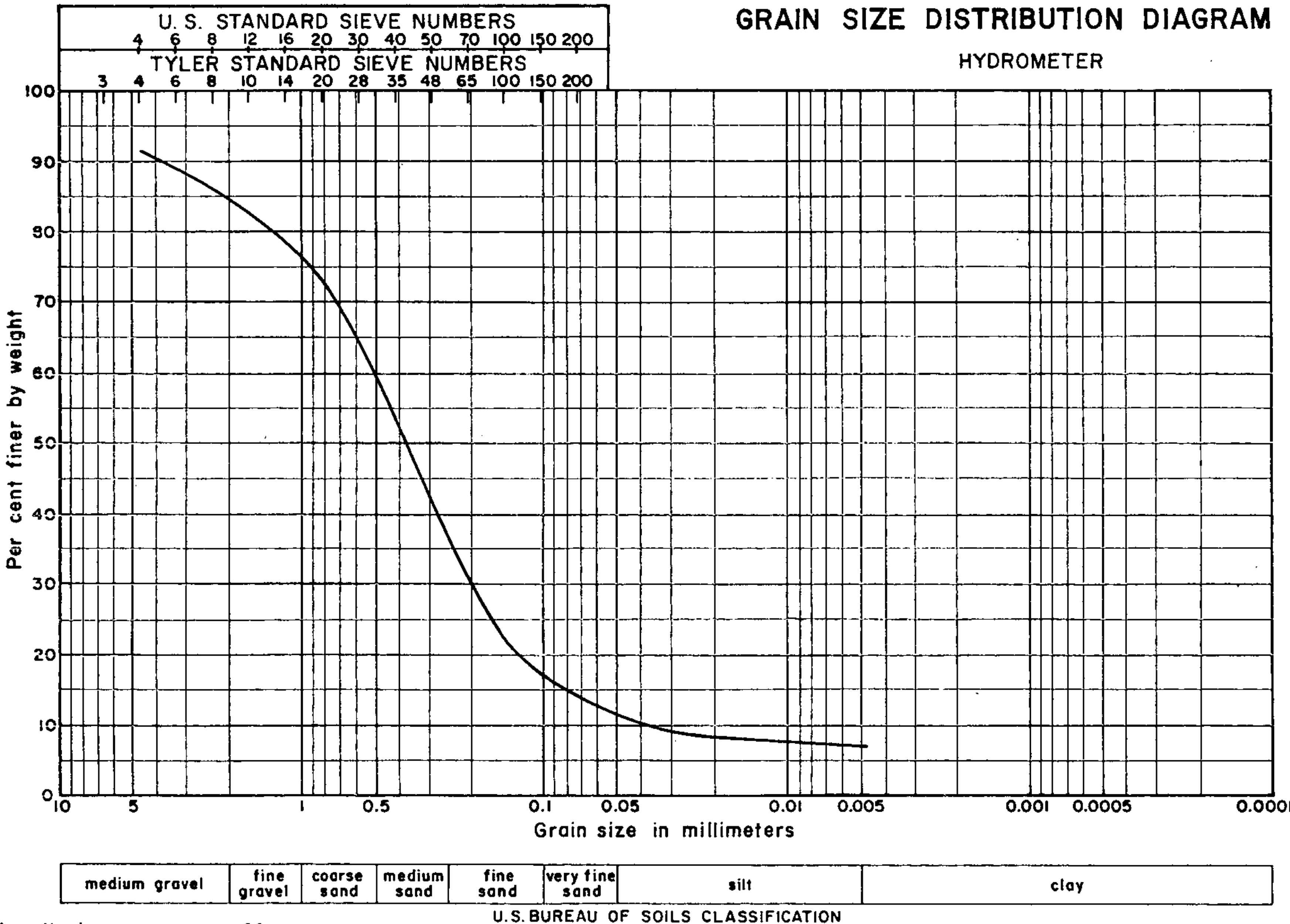
GRAIN SIZE DISTRIBUTION DIAGRAM



Boring Number: 11
Depth: 20 to 23 feet
Visual Classification: coarse sand
Estimated Permeability: 1×10^{-1} cm/sec.

FIGURE 33

BARR ENGINEERING CO.
Minneapolis, Minnesota



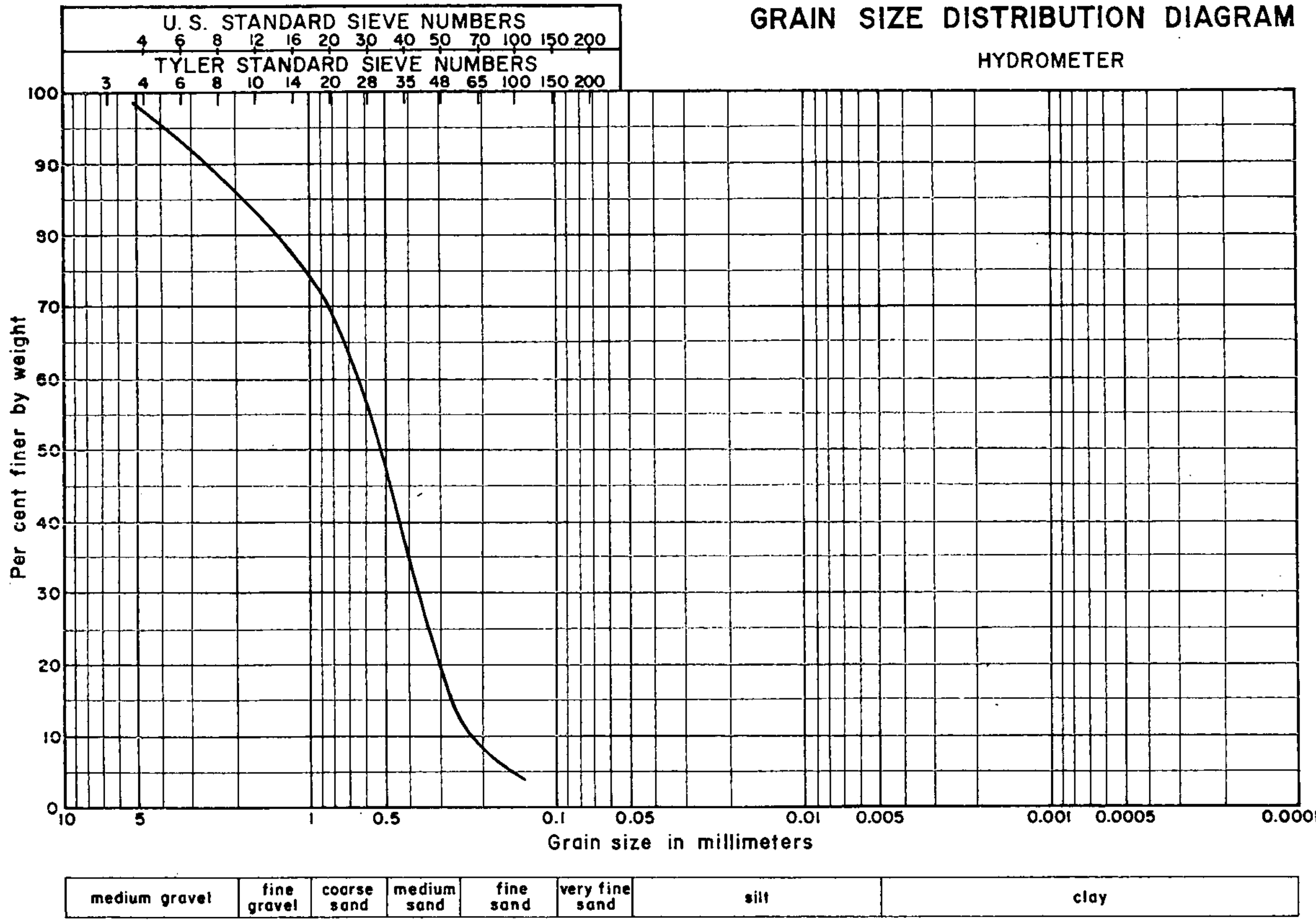
Boring Number: 11
Depth: 46 to 48 feet
Visual Contamination: red silty sand
Estimated Permeability: 1×10^{-3} cm/sec.

FIGURE 34

BARR ENGINEERING CO.
Minneapolis, Minnesota

GRAIN SIZE DISTRIBUTION DIAGRAM

HYDROMETER

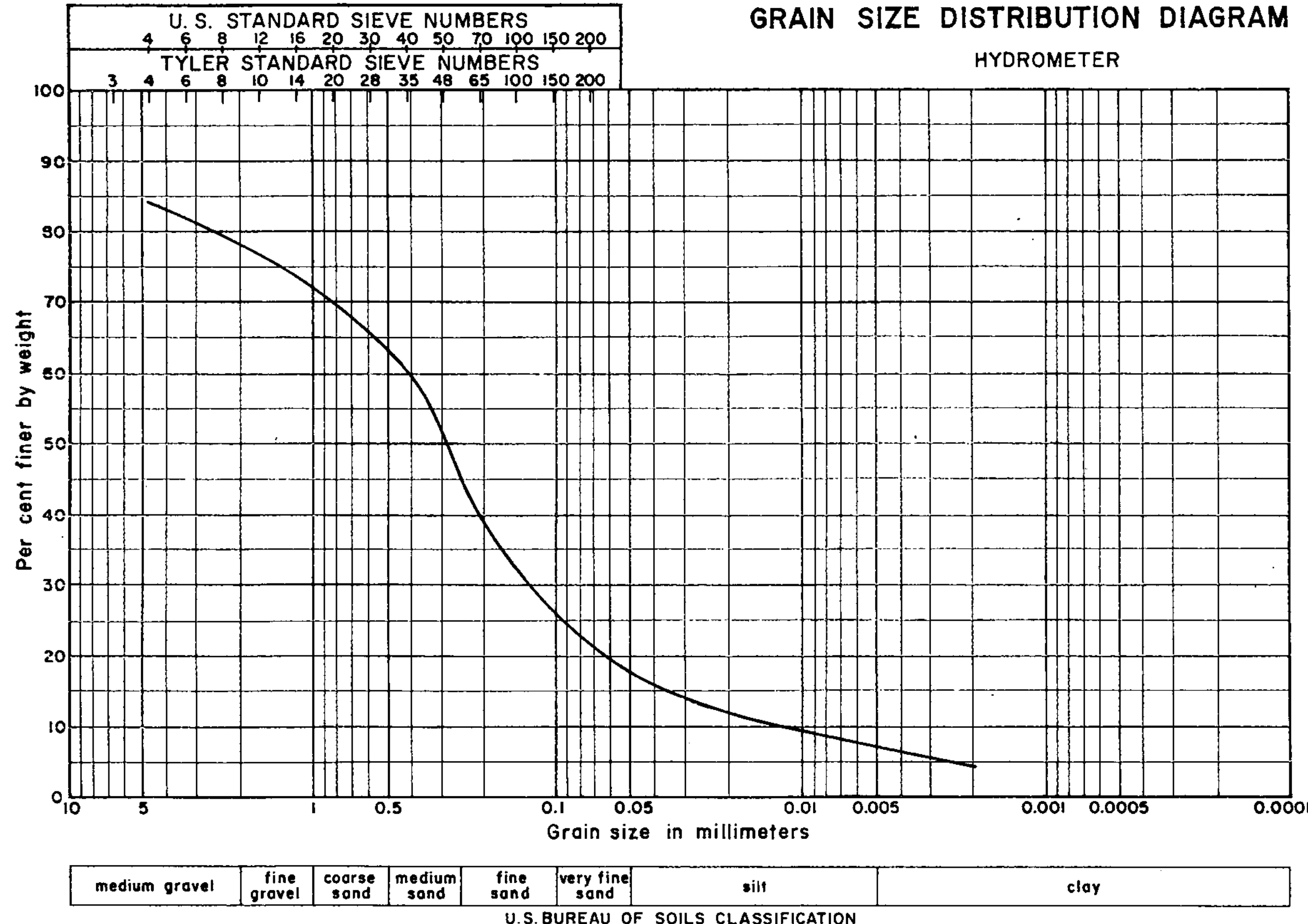


Boring Number: 12
Depth: 34 to 36 feet
Visual Classification: medium sand
Estimated Permeability: 5×10^{-2} cm/sec.

FIGURE 35

BARR ENGINEERING CO.
Minneapolis, Minnesota

GRAIN SIZE DISTRIBUTION DIAGRAM



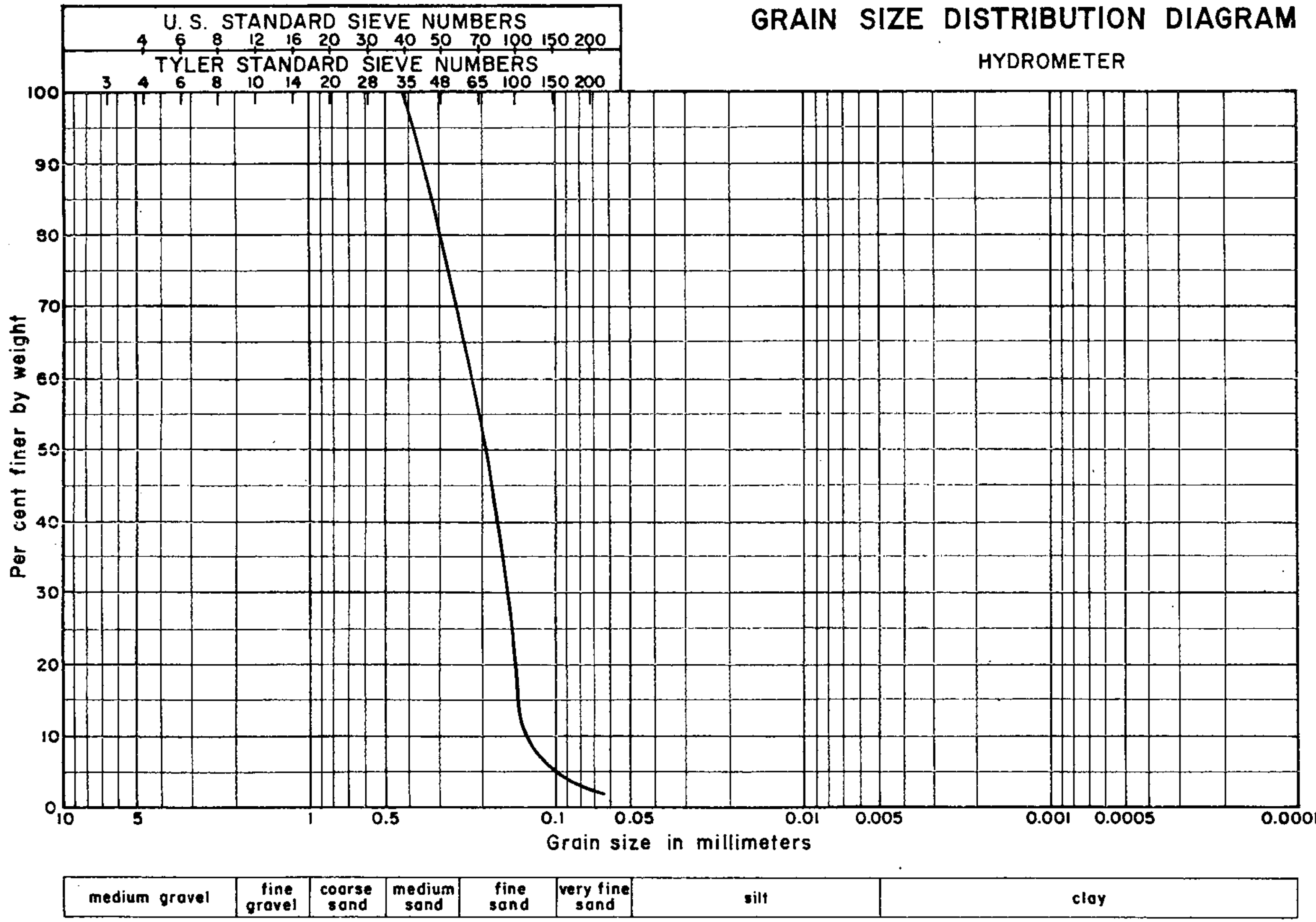
Boring Number: 12
Depth: 55 to 57 feet
Visual Classification: grey brown sandy clay
Estimated Permeability: 1×10^{-4} cm/sec.

FIGURE 36

BARR ENGINEERING CO.
Minneapolis, Minnesota

GRAIN SIZE DISTRIBUTION DIAGRAM

HYDROMETER



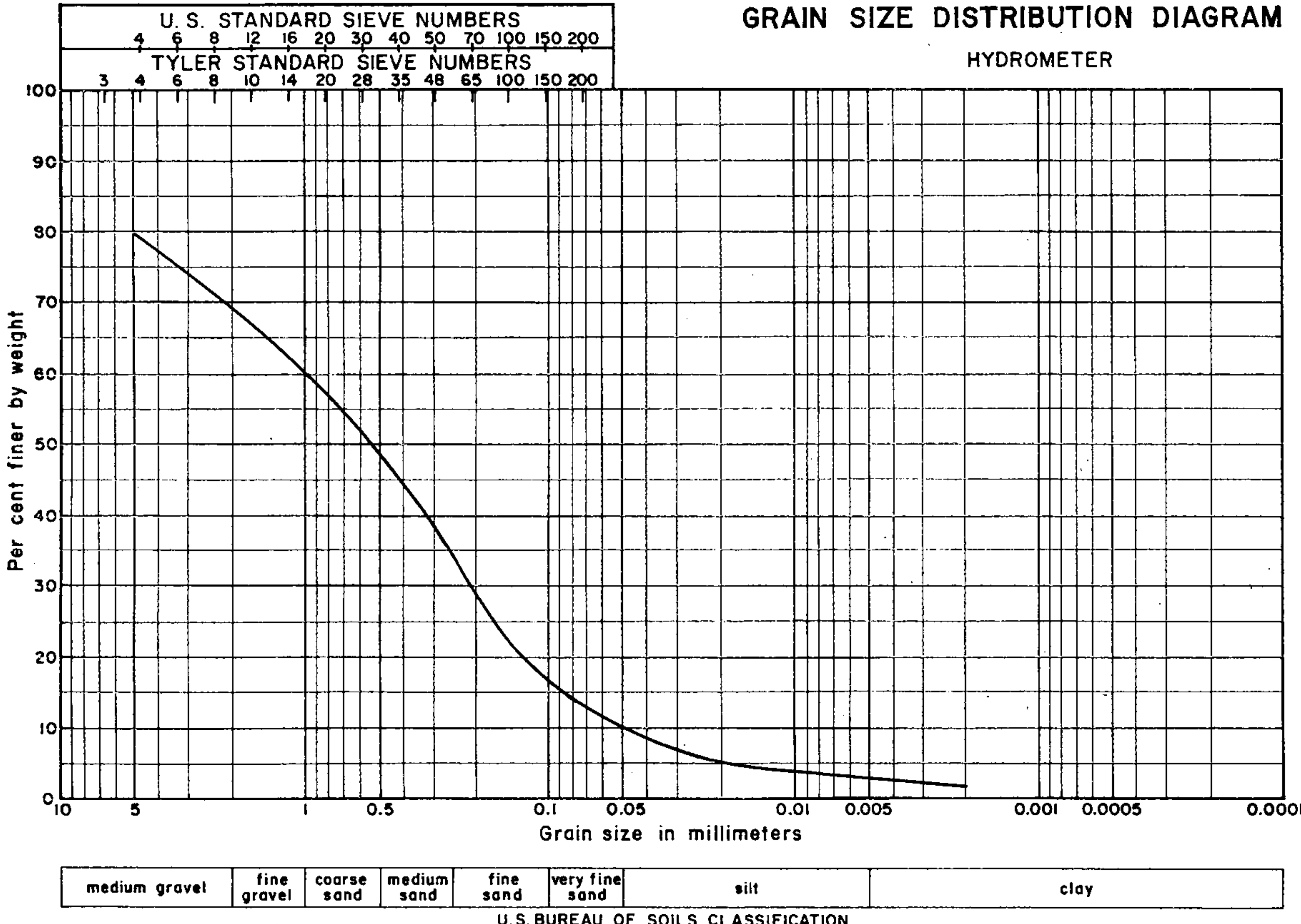
Boring Number: 13
Depth: 30 to 32 feet
Visual Classification: fine sand
Estimated Permeability: 1×10^{-2} cm/sec.

FIGURE 37

BARR ENGINEERING CO.
Minneapolis, Minnesota

GRAIN SIZE DISTRIBUTION DIAGRAM

HYDROMETER



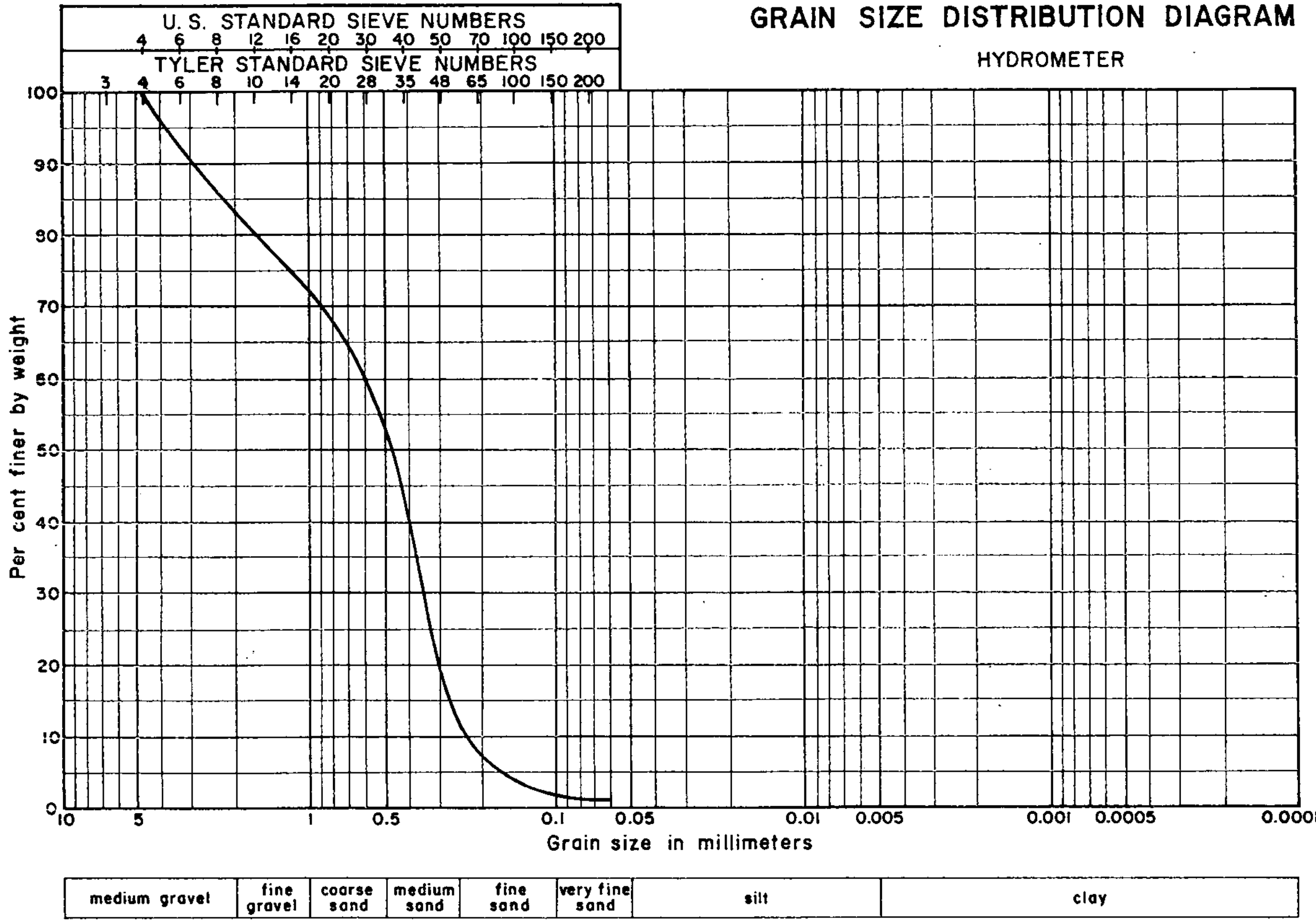
Boring Number:	13
Depth:	55 to 57 feet
Visual Classification:	fine silty sand
Estimated Permeability:	1 x 10^{-3} cm/sec.

FIGURE 38

BARR ENGINEERING CO.
Minneapolis, Minnesota

GRAIN SIZE DISTRIBUTION DIAGRAM

HYDROMETER

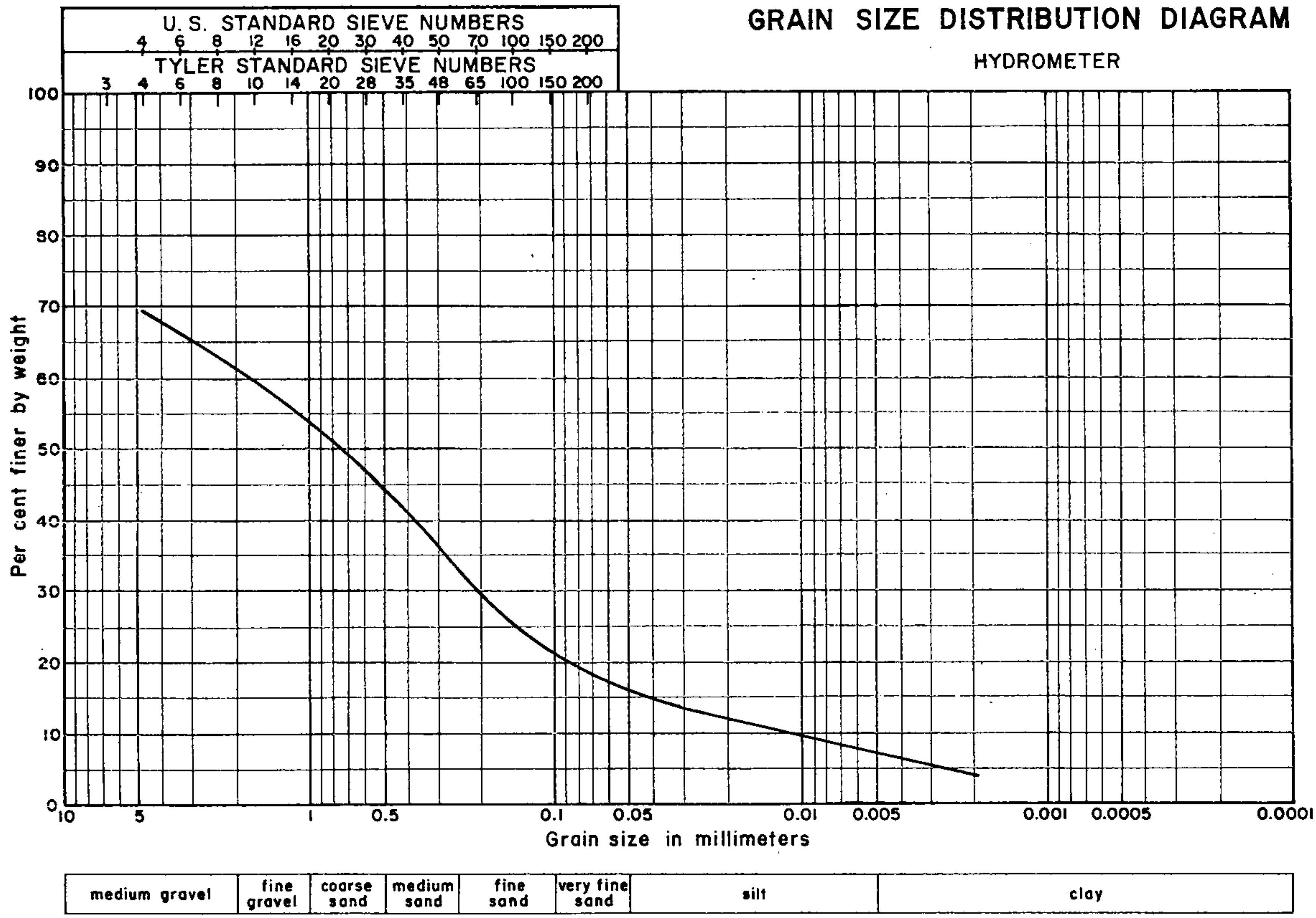


U.S. BUREAU OF SOILS CLASSIFICATION

Boring Number: 14
Depth: 54 to 56 feet
Visual Classification: medium sand
Estimated Permeability: 5×10^{-2} cm/sec.

FIGURE 39

BARR ENGINEERING CO.
Minneapolis, Minnesota



Boring Number: 14
Depth: 59 to 61 feet
Visual Classification: grey sandy clay
Estimated Permeability: 1×10^{-4} cm/sec.

Figure 40

BARR ENGINEERING CO.
Minneapolis, Minnesota

TABLE 1

SUMMARY OF THIN LAYER CHROMATOGRAPHY AND GAS CHROMATOGRAPHY DATA

MRI Sample Number	Boring	Depth (feet)	Soil Description	Phenol (mg/Kg)	Benzene Extractable (mg/Kg)	Qualitative (POM)	Benz(c) Phenanthrene (μg/g)	Chrysene (μg/g)	Benz(a) Pyrene (μg/g)
SS-105-1	5	5	Fill (Silty Sand)	6.6	9,300	Abundant	<0.2	10.0	<0.2
SS-105-2	5	15	Fine to Coarse Sand	1.2	1,100	*	<0.2	<3.2	<0.2
SS-105-3	5	30	Coarse Sand	<.2	155	Little	Not Quantitatively Analyzed		
SS-109-1	9	10-13	Peat	3.2	7,900	*	Not Quantitatively Analyzed		
SS-109B-1	9	30-32	Gravel	.8	735	*	0.36	49.0	0.93
SS-109A-1	9	32-33	Sand Below Thin Till Layer	.7	175	Little	Not Quantitatively Analyzed		
SS-109A-2	9	47-48	Coarse Sand	2.3	1,740	Abundant	0.25	474.5	6.9
SS-109B-2	9	48-49	Sandy Clay	7.8	170	Little	Not Quantitatively Analyzed		
SS-111-1	11	5-8	Peat	31.0	5,300	*	Not Quantitatively Analyzed		
SS-111-2	11	29-30	Medium Sand	1.1	90	*	<0.2	<3.2	<0.2
SS-111-3	11	39-42	Silty Sand	.4	85	Little	Not Quantitatively Analyzed		

*No qualitative estimate of the relative amount of fluorescent material was included in the MRI Report. Follow-up telephone conversations indicated that the * samples contained less fluorescent material than the samples labeled "abundant", but more than the samples labeled "little".

TABLE 2

CONSTRUCTION DATA - PHASE I MONITORING WELLS

Well No.	Elevation Top of Pipe (MSL)	Elevation Bottom of Well (MSL)	Depth (feet)	Comments
1	922.8	815.8	107	No screen, cased to top of Platteville, 5' of open hole in Platteville.
2	897.1	861.1	36	Screened in sand and gravel above upper till stratum.
3			52	Screened in gravel directly below approximately 45' of peat and muck.
5	891.8	865.8	25	Screened in sand and gravel above upper till stratum.
6	892.6	866.6	26	Screened in sand and gravel above upper till stratum.
7	930.0	860.0	70	Screened in fine sand directly below upper till stratum.
8	893.0	862.0	31	Screened in sand and gravel above upper till stratum.
9	891.3	866.3	25	Screened in sand and gravel above upper till stratum.
10	892.1	863.1	29	Screened in gravel above upper till stratum.

TABLE 3

PHASE I GROUND WATER QUALITY DATA

	Phase I Monitoring Wells									City Wells			Flame Ind.	Mid Co. Register [1]
Well	1	2	3	5	6	7	8	9	10	1	3	10		
Date	4/12/76	4/28/76		4/8/76	4/8/76	4/6/76	4/6/76	4/1/76	4/1/76	4/1/76	4/1/76	4/1/76	4/1/76	4/28/76
Lowest Formation	Platteville	Glacial Sand & Gravel	Glacial Sand & Gravel	Glacial Sand & Gravel	Glacial Sand & Gravel	Below Till	Glacial Sand & Gravel	Glacial Sand & Gravel	Glacial Sand & Gravel	St. Peter Sandstone	St. Peter Sandstone	Jordan Sandstone	Shakopee Dolomite	St. Peter Sandstone
Total Dissolved Solids (mg/1)	515	683	Well Destroyed	557	639	457	611	844	650	671	468	373	483	723
Specific Conductance (μmho's @ 25°C)	820	1,200		930	1,050	740	1,000	1,375	1,000	790	760	610	780	1,400
Total Alkalinity (mg/1 as $CaCo_3$)	319	366		410	366	282	342	528	472	344	316	340	340	454
Total Hardness (mg/1 as $CaCO_3$)	405	518		418	472	369	407	272	516	406	414	348	382	486
Phenolics (mg/1)	<.002	<.002		0.153	0.043 [2]	<.002	<.002	3.00	<.002	<.002	<.002	<.002	<.002	0.170 [4]
Benzene Extractables (mg/1)	<1	2		1	14 [3]	<1	<1	4	<1	<1	<1	<1	<1	2 [5]

(1) Formerly Robinson Rubber Company

(2) Analysis on duplicate sample indicated .053 mg/1

(3) Analysis on duplicate sample indicated 4 mg/1

(4) Analysis on duplicate sample indicated .190 mg/1

(5) Analysis on duplicate sample indicated 1 mg/1

TABLE 4

ESTIMATED PERMEABILITIES IN GLACIAL SOILS

Boring Number	Sample Depth (feet)	Visual Soil Description	D_{80}	D_{40}	D_{10}	Permeability (cm/sec.)	Grain-Size Distribution Shown Figure No.
6	54-56	Red Silty Sandy Clay Till	4	.08	.003	5×10^{-6}	31
9	25-28	Green-Grey Clay	1.3	.5	.005	1×10^{-5}	32
11	20-23	Coarse Sand	1	.6	.3	1×10^{-1}	33
11	46-48	Red Silty Sand	1.5	.3	.03	1×10^{-3}	34
12	34-36	Medium Sand	1.5	.4	.2	5×10^{-2}	35
12	55-57	Grey-Brown Sandy Clay	3	.2	.01	1×10^{-4}	36
13	30-32	Fine Sand	.3	.2	.15	1×10^{-2}	37
13	55-57	Fine Silty Sand	5	.3	.05	1×10^{-3}	38
14	54-56	Medium Sand	2	.4	.2	5×10^{-2}	39
14	59-62	Red Sandy Clay	>5	.4	.01	1×10^{-4}	40

APPENDIX A

LABORATORY REPORT

INSTITUTE FOR RESEARCH

HOUSTON, TEXAS

INSTITUTE FOR RESEARCH, INC.
8330 WESTGLEN DR. • HOUSTON, TEXAS 77042 • 713/783-8400

January 19, 1976

Mr. Bill O'Connor
Serco Laboratory
2982 N. Cleveland Ave.
Roseville, Minn. 55113

Analytical Report

SUBJECT: Mass Spectrometry - Gas Chromatography Examination of Samples GCMS-2 (10-20-75) and GCMS-3 supernatant (10-22-75)

METHOD: Mass Spectrometry
Gas Chromatography
Infra-red Spectroscopy

RESULTS: The samples were extracted with toluene in a soxhlet extraction for 48 hours and the toluene extract introduced directly into the Finnigan MS-GC instrument.

Sample GCMS-2 was found to contain several condensed ring aromatics along with terpene-like materials as given as follows:

(1)	Terpineols (terpene alcohols)	Minor
(2)	Anthracene	Minor
(3)	Phenanthrene	Minor
(4)	α - pyrene	Slight Trace
(5)	α - benzopyrene	Very Slight Trace (<5ppm)

Sample GCMS-3 was also found to contain small amounts of terpene alcohols and trace amounts of polynuclear hydrocarbons (anthracene and/or phenanthrene). No evidence was found of any pyrene type compounds.

Infra-red examination of the solids removed from sample 2 verifies the presence of terpeneols as well as condensed ring aromatics. Sample #3 could not be concentrated sufficiently to obtain a well-defined infra-red spectra.

COMMENTS: Polynuclear hydrocarbons such as anthracene and phenanthrene appear to be characteristic of the solids present in sample #2. "Fingerprinting" with these types of functional groups should be characteristic of the type samples submitted (based on solids composition). Potential carcinogens as α - benzopyrene are present at very low concentrations in sample #2 and found to be totally absent in the supernatant liquid (#3).

Respectfully submitted,

Benjamin Mosier

Benjamin Mosier, Ph.D.
President

BM/mw

APPENDIX B

LABORATORY REPORT
SERCO LABORATORIES, INC.
MINNEAPOLIS, MINNESOTA

ANALYTICAL DATA AND PROCEDURES
BARR ENGINEERING - ST. LOUIS PARK
SOIL & GROUNDWATER STUDY
PHASE I
JANUARY - APRIL, 1976

Prepared by: William A. O'Connor, Chemist
Director of Laboratory Services
SERCO Laboratories
2982 North Cleveland Avenue
Roseville, Minnesota 55113

Dated: May 14, 1976

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I	Laboratory Procedures for Phenol and Extractables
II	Evaluation of Procedures for Reporting Percent Solids

I. INTRODUCTION

This is a report of the laboratory data generated at SERCO Laboratories for Barr Engineering Company with regard to Phase I of the St. Louis Park soil and groundwater study. Soil and well water samples were delivered to SERCO Laboratories between January 21, 1976 and April 28, 1976. The soil samples were collected from fourteen soil borings at five-foot intervals in the soil profile. The objective of the analysis of the soil samples was to determine the phenolics, benzene extractables and percent solid content of each soil sample. A total of 196 soil samples were analyzed for these parameters. In addition, duplicate analyses were performed on 10% of the samples for benzene extractables, phenolics and percent solids. The analytical data for the soil samples are presented in Tables I through XIV.

Well water samples from thirteen locations were collected by Barr Engineering Company and delivered to SERCO Laboratories. These samples were analyzed for total dissolved solids, specific conductance, total alkalinity, total hardness, phenolics and benzene extractables. The analytical data for the well water samples are presented in Table XV.

The report includes documentation of all analytical procedures utilized in the analysis of the soil and water samples. It includes a description of the procedures used to obtain representative sub-samples from the soil and also lists the preservation procedures which were employed to maintain the integrity of the sample from the time of collection until the analyses could be performed.

II. ANALYTICAL PROCEDURES

This section includes the description of the preservation techniques, special sample preparation procedures employed prior to analysis and the methodologies used to carry out the analytical measurements.

A. Sample Preservation and Storage

In order to insure that the integrity of both soil and water samples were maintained from the time of collection until the analyses were performed, proper bottle types and preservation techniques were used. Table XVI provides a listing of the bottle type, chemical preservative and temperature at which the soil and water samples were stored until the analysis could be completed. All soil samples were frozen and stored at Polar Food Locker, Inc. at -4^{o}C until analyzed. A time delay of two to four hours occurred between the time the samples were collected until delivery to Polar Food Locker, Inc. All bottles used for the collection of well water samples contained the appropriate chemical preservative where applicable to insure the immediate preservation of the sample at the time of collection. The water samples were then stored at 4^{o}C upon receipt at SERCO Laboratories until the analyses could be completed.

B. Sample Preparation

All soil samples were delivered to SERCO Laboratories from Polar Locker in a frozen state. Prior to analysis, the samples were thawed at room temperature for three to four hours. All soil samples were analyzed the same day that they were thawed. The soil samples analyzed represented a wide spectrum of soil types, including peat, clay, sand, gravel, and combinations thereof. Because of concentration gradients of the creosote material throughout a soil sample, it was difficult to obtain a truly representative sub-sample from each soil analyzed. The technique employed for obtaining a representative sub-sample was dependent upon the physical form of the sample and the number of soil types contained in each soil sample. Several samples had retained the form of the sampler which had been used to collect the soil sample. These samples were homogeneous with regard to soil type. Sub-samples in this case were obtained by cutting the core or mold into four equal sub-sections using a stainless steel spatula. The sample for analysis was obtained from the center of the sub-sections. Samples which did not retain the form of the sampler used for sample collection, but had an undefined form, were both homogeneous and non-homogeneous in terms of soil type. In the case of a homogeneous soil type, the sample was thoroughly mixed in the sample bottle with a stainless steel spatula before obtaining a representative sub-sample from the bottle. However, if the sample consisted of more than one soil type, the sample was segregated according to soil types, each soil type was mixed thoroughly with the stainless steel spatula and a representative amount of each soil type was sub-sampled and composited prior to analysis. For example, if a sample consisted of 50% cohesive soil and 50% granular soil, the sample would have been split roughly into the individual cohesive and granular portions. Each portion would have then been mixed thoroughly and if 100 grams were required for the analysis, 50 grams of the granular and 50 grams of the cohesive soil would have been composited for the analysis.

Once a representative sample had been obtained from the sample bottle, it was then necessary to employ a sub-sampling technique which would yield a sample of uniform particle size and be representative of the possible concentration gradients occurring throughout the sample. After some preliminary experimentation within our laboratory, the best technique for achieving a representative sub-sample was found to be the quartering sample technique (see Appendix I). In quartering, the soil was spread uniformly over a sheet of aluminum foil, all stones larger than approximately 3 mm in diameter were picked out with a stainless steel tweezers and discarded. The sample was then mixed and divided into four equal portions. Two of the portions were randomly selected and returned to cold storage and the remaining portions were again mixed together, spread out again, and reduced to half by the same procedure; then one of the four equal portions was randomly collected for analysis. Twenty grams of the quartered sub-sample were used to measure the concentration of benzene extractables and approximately five grams of the quartered sub-sample were used to measure the concentration of phenolic material. All mixing was accomplished by the use of a stainless steel spatula.

C. Methodologies

The analytical methodologies employed for the analysis of the soil and well water samples are given in Table XVII. The procedure given in the 13th Edition of Standard Methods for the Examination of Water and Wastewater for the determination of benzene extractables was modified by substituting benzene as the solvent in place of freon. Due to the extremely high concentrations of creosote-like material in some of the soil samples, there was a possibility that the four-hour reflux time given in Standard Methods for the Soxhlet extraction procedure might not be sufficient to remove all benzene extractables in the soil. Therefore, a preliminary study was conducted at SERCO Laboratories which demonstrated a 98% removal of all benzene extractables within the four-hour reflux period (See Appendix I). Because of the possible degradation of the benzene extractables or phenols in the soil samples due to biological activity or chemical oxidation, all analyses on the soil samples were conducted the same day that the samples were removed from the freezer and thawed. After the analysis had been completed, the sample bottles were replaced in the freezer.

In selecting a method for the percent solids determination, consideration was given to the possible loss of volatile organic matter by heating the sample in an oven at 105°C as opposed to air drying the samples at room temperature. To determine if there would be a significant loss of volatile organic matter, by heating the sample at 105°C, a comparative study was conducted at SERCO Laboratories between the oven-dried and air-dried procedures (See Appendix II). A wide variety of sample types were analyzed including fine sand, clay and peat samples. The results between the oven-dried and air-dried procedures for all samples types showed good comparability, a standard deviation of ±2.1%. Therefore, the methodology selected for the determination of percent solids was the oven-dried procedure.

III. ANALYTICAL DATA

The analytical data for the soil samples are given in Tables I through XIV. It should be noted that, although the soil samples were frozen immediately after collection, they were not thawed until the day of analysis. In several cases, there was a time lapse of several months between the time of sample collection and the analytical determination. Lower detection limits than those reported on the soil samples for the phenol determinations could have been obtained by the analytical procedure if a larger sample size could have been used. However, this was not possible due to severe bumping during distillation as a result of large amounts of sand and silt in many of the soil samples. Many of the soil samples with the lowest phenol concentrations contained the largest amounts of sand and silt.

On many of the samples that exhibited a strong odor, it was noted that after standing at room temperature for 3-4 hours, the odor diminished. On April 13, 1976, a bentonite drilling mud sample was delivered to SERCO Laboratories by Barr Engineering for an analysis of benzene extractables and phenol. A concentration of 0.02 mg/l for phenol and 24 mg/l for benzene extractables was obtained.

IV. QUALITY CONTROL DATA

Approximately 10% of all soil samples analyzed were run in duplicate for benzene extractables, phenols and percent solids. The duplicate sample was obtained from a second quarter of the sub-sample. This data are presented in Table XVIII. Good precision was obtained for the phenols and percent solids which yielded a relative standard deviation (RSD) of 1% and 0.8% respectively. The calculation of the RSD for phenols was based upon ten sets of data and the RSD for percent solids on thirteen sets of data. Any value reported as 'less than' the detection limit was not included in the calculation.

The RSD for benzene extractables was 37% based upon a sample population of thirteen sets of data. This relatively high degree of variability may be reflective of: 1) precision of the Soxhlet extraction procedure; 2) difficulty encountered in obtaining a representative soil sample; and 3) complexity of the sample matrix being analyzed.

This report and laboratory analyses reported herein have been prepared by myself or under my direct supervision.

Submitted by:

SERCO LABORATORIES

William A. O'Connor, Chemist
Director of Laboratory Services

May 14, 1976

TABLE I

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 1
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight (1)	Phenol mg/kg, Dry Weight (1)
5	11-14-75	4-8-76	625	<0.2	89.5	700	<0.2
10	11-14-75	4-8-76	1,685	<0.2	76.8	2,200	<0.2
15	11-14-75	4-7-76	<50	<0.2	91.1	<55	0.2
20	11-14-75	4-8-76	140	<0.2	89.3	155	<0.2
25	11-18-75	4-8-76	110	<0.2	86.1	130	<0.2
30	11-18-75	4-9-76	<50	<0.2	83.4	<60	<0.2
35	11-18-75	4-9-76	95	<0.2	87.2	110	<0.2
40	11-18-75	4-9-76	55	<0.2	84.3	65	<0.2
45	11-18-75	4-9-76	65	<0.2	82.9	80	<0.2
50	11-18-75	4-12-76	75	<0.2	90.6	85	<0.2
55	11-19-75	4-12-76	95	0.8	80.2	120	1.0
60	11-25-75	4-12-76	80	<0.2	83.5	95	<0.2
65	11-25-75	4-12-76	105	0.5	83.1	125	0.6
75	11-25-75	4-13-76	170	0.8	85.0	200	0.9

(1) Dry weight values calculated by Barr Engineering

TABLE II

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 2
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight (1)	Phenol mg/kg, Dry Weight (1)
7.5	11-26-75	4-13-76	2,865	0.8	87.8	3,460	1.0
10	11-26-75	4-13-76	1,845	0.8	60.5	3,050	1.3
15	11-26-75	4-13-76	185	0.8	82.3	225	1.0
20	11-26-75	4-13-76	110	0.5	88.0	125	0.6
25	11-26-75	4-13-76	85	0.5	82.9	105	0.6
40	11-26-75	4-13-76	95	0.2	91.7	105	0.2
45	11-26-75	4-13-76	105	0.5	93.0	115	0.5

(1) Dry weight values calculated by Barr Engineering

TABLE III

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 3
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight[1]	Phenol mg/kg, Dry Weight[1]
2.5	12-3-75	4-13-76	8,420	2.0	82.2	10,200	2.4
5	12-3-75	4-13-76	435	2.2	77.8	560	2.8
7.5	12-3-75	4-14-76	3,230	0.3	19.7	16,400	1.5
10	12-3-75	4-14-76	2,660	0.2	26.9	9,890	0.7
15	12-3-75	4-13-76	145	0.5	78.3	185	0.6
20	12-3-75	4-14-76	<50	<0.2	88.0	<55	<0.2
30	12-3-75	4-15-76	<50	1.0	86.7	<60	1.2
35	12-3-75	4-14-76	70	<0.2	84.9	80	<0.2
40	12-3-75	4-14-76	115	0.2	93.0	125	0.2
50	12-3-75	4-14-76	95	<0.2	89.2	105	<0.2
55	12-4-75	4-14-76	90	0.2	85.7	105	0.2
60	12-4-75	4-14-76	175	<0.2	91.4	190	<0.2
70	12-4-75	4-14-76	95	0.4	93.3	100	0.4

[1] Dry weight values calculated by Barr Engineering

TABLE IV

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 4
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight(1)	Phenol mg/kg, Dry Weight(1)
2.5	12-11-75	4-14-76	37,900	22.5	85.4	44,400	26.3
5	12-11-75	4-14-76	25,200	13.3	88.0	28,600	15.1
7.5	12-11-75	4-14-76	54,800	38.8	86.2	63,600	45.0
10	12-11-75	4-15-76	63,100	70.0	33.5	188,400	209
12.5	12-11-75	4-15-76	11,200	11.6	78.0	14,400	14.9
15	12-11-75	4-15-76	545	2.2	85.5	640	2.6
17.5	12-11-75	4-16-76	<50	<0.2	83.9	<60	<0.2
20	12-11-75	4-14-76	250	1.0	89.0	280	1.1
25	12-11-75	4-15-76	1,195	2.0	87.0	1,380	2.3
30	12-11-75	4-15-76	180	1.5	87.6	205	1.7
35	12-11-75	4-15-76	140	0.5	83.5	170	0.6
40	12-12-75	4-16-76	<50	<0.2	92.3	<55	<0.2
50	12-12-75	4-16-76	50	0.4	87.9	55	0.5
55	12-12-75	4-16-76	<50	0.[illegible]	84.5	<60	0.2
60	12-12-75	4-16-76	85	0.4	87.6	100	0.5

(1) Dry weight values calculated by Barr Engineering

TABLE V

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 5
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight[1]	Phenol mg/kg, Dry Weight[1]
5	12-16-75	4-19-76	7,900	5.6	85.0	9,300	6.6
10	12-16-75	4-19-76	3,730	4.0	77.2	4,830	5.2
15	12-18-75	4-14-76	960	1.0	86.8	1,100	1.2
20	12-19-75	4-19-76	130	<0.2	84.9	155	<0.2
27.5	12-19-75	4-19-76	95	<0.2	83.6	115	<0.2
30	12-19-75	4-19-76	135	<0.2	86.8	155	<0.2
34-35	12-30-75	4-19-76	175	<0.2	91.5	190	<0.2
39-40	12-30-75	4-20-76	60	<0.2	89.1	65	<0.2
44-45	12-30-75	4-20-76	<50	<0.2	87.5	<55	<0.2
49-50	12-30-75	4-20-76	80	0.2	89.7	90	0.2
54-55	12-30-75	4-20-76	60	<0.2	89.0	65	<0.2
59-60	12-30-75	4-20-76	55	<0.2	86.8	65	<0.2
64-65	12-30-75	4-21-76	50	<0.2	93.4	55	<0.2
69-70	12-30-75	4-21-76	<50	<0.2	89.0	<55	<0.2

(1) Dry weight values calculated by Barr Engineering

TABLE VI

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 6
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight[1]	Phenol mg/kg, Dry Weight[1]
2.5-4	1-19-76	3-10-76	495	1.1	91.6	540	1.2
5-7	1-9-76	3-10-76	3,160	2.2	24.2	13,100	9.1
10-11.5	1-9-76	3-10-76	75	1.1	89.0	85	1.2
15-17	1-9-76	3-10-76	60	0.9	89.3	65	1.0
20-22	1-9-76	3-10-76	80	0.6	95.1	85	0.6
22-23.5	1-9-76	3-10-76	80	0.7	84.9	95	0.8
25-26.5	1-10-76	3-11-76	<50	0.2	80.8	<50	0.2
30-32.5	1-10-76	3-11-76	<50	0.3	82.2	<50	0.4
34-36	1-10-76	3-11-76	<50	0.3	87.8	<50	0.3
40.5-42.5	1-10-76	3-11-76	65	1.2	84.7	75	1.4
44-46	1-10-76	3-11-76	90	0.5	88.8	100	0.6
49-51	1-10-76	3-12-76	115	0.8	88.5	130	0.9
54-55	1-10-76	3-12-76	930	0.8	89.1	1,050	0.9
59-60	1-11-76	3-12-76	140	0.5	92.9	150	0.5
70-72	1-11-76	3-11-76	1,600	4.6	90.6	1,770	5.1

(1) Dry weight values calculated by Barr Engineering

TABLE VII

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 7
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight(1)	Phenol mg/kg, Dry Weight(1)
5	12-23-75	4-21-76	<50	<0.2	87.9	<55	<0.2
10	12-23-75	4-21-76	110	<0.2	89.0	125	<0.2
12.5	12-23-75	4-21-76	65	<0.2	90.2	70	<0.2
15	12-23-75	4-21-76	90	<0.2	83.6	110	<0.2
20	12-23-75	4-21-76	<50	<0.2	86.7	<60	<0.2
25	12-23-75	4-21-76	<50	<0.2	87.7	<55	<0.2
30	12-30-75	4-21-76	95	0.2	86.9	110	0.2
35	12-30-75	4-21-76	<50	<0.2	82.2	<60	<0.2
40	12-30-76	4-21-76	60	<0.2	86.7	70	<0.2
45	12-30-75	4-21-76	<50	<0.2	84.6	<60	<0.2

(1) Dry weight values calculated by Barr Engineering

TABLE VIII

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 8
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight (1)	Phenol mg/kg, Dry Weight (1)
2-4	1-13-76	3-12-76	3,360	8.4	16.8	20,000	50.0
5-7	1-13-76	3-12-76	2,425	25.0	14.6	16,600	171.0
7-9	1-13-76	3-18-76	8,220	7.8	34.9	23,600	22.3
10-12	1-13-76	3-18-76	1,170	0.4	59.9	1,960	0.7
15.5-17A	1-13-76	3-18-76	15,490	7.3	87.2	17,800	8.4
15.5-17B	1-13-76	3-18-76	1,055	1.0	55.8	1,890	1.8
20-22	1-13-76	3-18-76	13,550	5.3	89.0	15,200	6.0
25-27	1-13-76	3-18-76	3,740	2.8	86.5	4,330	3.2
29-32	1-13-76	3-19-76	75	0.7	89.2	85	0.8
32-33.5	1-13-76	3-19-76	105	0.7	89.4	115	0.8
35-36	1-13-76	3-19-76	75	1.3	87.0	85	1.5
39-41	1-13-76	3-19-76	75	0.7	-	-	-
44-46	1-13-76	3-20-76	75	2.4	85.3	90	2.8
49-51	1-13-76	3-19-76	1,705	<0.2	92.0	1,860	0.2
54-55	1-13-76	3-19-76	115	0.4	91.9	125	0.4
59-61	1-13-76	3-20-76	65	2.2	89.8	70	2.4
66-67.5	1-13-76	3-20-76	65	2.2	87.6	75	2.5
69-71	1-13-76	3-20-76	95	2.4	89.5	105	2.7

(1) Dry weight values calculated by Barr Engineering

TABLE IX

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 9
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight (1)	Phenol mg/kg, Dry Weight (1)
2-4	1-15-76	3-23-76	2,640	3.0	20.3	13,000	14.8
5-8	1-15-76	3-24-76	2,630	<0.2	20.8	12,600	<1.0
10-13	1-15-76	3-23-76	2,450	1.0	31.0	7,900	3.2
15-18	1-15-76	3-24-76	1,210	1.0	42.0	2,880	2.4
20-23	1-16-76	3-24-76	1,070	0.4	50.4	2,120	0.8
25-28	1-16-76	3-24-76	1,970	1.8	16.0	12,300	11.3
30-33A	1-15-76	3-23-76	150	0.6	85.7	175	0.7
30-33B	1-15-76	3-23-76	560	0.6	76.1	735	0.8
35-38	1-19-76	3-24-76	130	1.8	81.9	160	2.2
38.5-40.5	1-16-76	3-25-76	55	0.4	85.3	65	0.5
40-41.5	1-19-76	3-25-76	55	0.2	84.4	65	0.2
47.5-49A	1-19-76	3-23-76	1,530	2.0	88.2	1,740	2.3
47.5-49B	1-19-76	3-23-76	145	6.6	85.0	170	7.8
51-52.5	1-15-76	3-25-76	100	0.6	82.7	120	0.7
53-55.5	1-16-76	3-25-76	70	0.6	90.5	75	0.7
58-60.5	1-15-76	3-25-76	125	0.6	86.6	145	0.7
63-65.5	1-15-76	3-25-76	75	0.2	88.8	85	0.2
69-71	1-15-76	4-2-76	80	<0.2	93.4	85	<0.2

(1) Dry weight values calculated by Barr Engineering

TABLE X

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 10
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight[1]	Phenol mg/kg, Dry Weight[1]
5-8	1-20-76	3-26-76	57,400	280	18.7	307,000	1,500
10-13	1-20-76	3-26-76	74,000	220	33.8	219,000	650
15-18	1-20-76	3-26-76	1,910	12.5	84.4	2,270	14.8
18-21	1-22-76	3-26-76	1,000	5.5	87.2	1,150	6.3
20-23	1-20-76	3-26-76	2,940	5.0	91.0	3,230	5.5
25-27	1-21-76	3-29-76	8,620	16.0	84.3	10,200	19.0
27-30	1-21-76	3-29-76	1,180	4.0	86.4	1,370	4.6
30-33	1-21-76	3-29-76	150	0.6	86.6	175	0.7
38.5-40.5A	1-20-76	3-29-76	80	2.8	90.2	90	3.1
38.5-40.5B	1-20-76	3-29-76	160	2.2	90.1	180	2.4
45-47.5	1-20-76	3-29-76	55	0.6	88.6	60	0.7
50.5-52	1-20-76	3-30-76	135	0.6	86.5	155	0.7
53-55.5	1-20-76	3-30-76	90	0.6	92.3	100	0.7
58-60.5	1-20-76	3-30-76	125	0.8	91.9	135	0.9
64.5-67	1-20-76	3-30-76	125	0.2	89.0	140	0.2

[1] Dry weight values calculated by Barr Engineering

TABLE XI

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 11
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight[1]	Phenol mg/kg, Dry Weight[1]
2-5A	1-22-76	3-30-76	305	0.4	88.0	345	0.5
2-5B	1-22-76	3-31-76	4,160	10.4	20.0	20,800	52.0
5-8	1-22-76	3-31-76	1,945	11.4	36.7	5,300	31.0
10-13	1-22-76	3-31-76	255	0.2	45.8	555	0.4
15-17	1-26-76	3-31-76	115	0.6	81.9	140	0.7
20-23	1-22-76	3-31-76	120	0.2	84.4	140	0.2
29-31.5	1-22-76	4-1-76	80	1.0	89.1	90	1.1
39-41.5	1-22-76	4-1-76	75	0.4	90.4	85	0.4
46-48	1-22-76	3-31-76	80	<0.2	90.4	90	<0.2
50-52.5	1-22-76	3-31-76	100	<0.2	88.2	115	<0.2
54-56.5A	1-22-76	3-31-76	70	<0.2	92.9	75	<0.2
54-56.5B	1-22-76	3-31-76	<50	<0.2	88.4	<55	<0.2
59-61.5	1-22-76	3-31-76	50	<0.2	89.5	55	<0.2
65-65.5	1-22-76	3-31-76	120	<0.2	86.7	140	<0.2

[1] Dry weight values calculated by Barr Engineering

TABLE XII

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 12
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight[1]	Phenol mg/kg, Dry Weight[1]
3-5	1-26-76	4-1-76	23,500	12.4	20.3	116,000	61.0
5-7	1-26-76	4-1-76	32,300	9.6	23.1	140,000	42.0
9.5-11.5	1-26-76	4-1-76	9,680	1.4	83.2	11,600	1.7
14.5-16	1-26-76	4-1-76	115	2.4	80.1	145	3.0
22-23	1-28-76	4-1-76	75	0.4	85.4	90	0.5
25-27	1-28-76	4-1-76	225	0.4	83.5	270	0.5
29-31	1-28-76	4-1-76	115	<0.2	85.0	135	<0.2
34-36	1-28-76	4-1-76	95	0.2	87.9	110	0.2
39-41	1-28-76	4-1-76	185	<0.2	84.5	220	<0.2
44-46	1-28-76	4-2-76	215	0.2	86.7	250	0.2
49-51	1-28-76	4-2-76	55	<0.2	85.6	65	<0.2
54-56	1-28-76	4-2-76	100	<0.2	86.2	115	<0.2
55-57	1-28-76	4-2-76	60	<0.2	91.0	65	<0.2
65	12-17-75	4-2-76	75	<0.2	90.4	85	<0.2

(1) Dry weight values calculated by Barr Engineering

TABLE XIII

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 13
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight[1]	Phenol mg/kg, Dry Weight[1]
2-5	1-28-76	4-2-76	890	5.4	87.2	1,020	6.2
5-8	1-28-76	4-2-76	120	0.4	92.9	130	0.4
10-13	1-28-76	4-2-76	245	0.4	83.9	290	0.5
15-18	1-28-76	4-2-76	195	0.4	86.7	225	0.5
20-23	1-28-76	4-2-76	170	0.2	81.4	210	0.2
25-27.5	1-28-76	4-6-76	<50	0.8	80.5	<60	1.0
30-32.5	1-28-76	4-6-76	<50	0.6	80.5	<60	0.7
35-37.5	1-28-76	4-2-76	<50	<0.2	86.5	<60	<0.2
40-42.5	1-28-76	4-5-76	75	<0.2	87.6	85	<0.2
49-51.2	1-28-76	4-2-76	70	<0.2	91.0	75	<0.2
55-57	1-28-76	4-5-76	90	<0.2	90.7	100	<0.2

(1) Dry Weight values calculated by Barr Engineering

TABLE XIV

ANALYTICAL DATA OF SOIL SAMPLES
BORING NUMBER 14
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Depth, Feet	Date Collected	Date Analyzed	Benzene Extractable mg/kg, Wet Weight	Phenol mg/kg, Wet Weight	Percent Solids	Benzene Extractable mg/kg, Dry Weight[1]	Phenol mg/kg, Dry Weight[1]
2.5-5A	1-29-76	4-5-76	2,480	0.8	84.6	2,930	0.9
2.5-5B	1-29-76	4-7-76	450	0.4	91.9	490	0.4
5-7.5A	1-29-76	4-6-76	17,100	3.3	87.5	19,500	3.8
5-7.5B	1-29-76	4-6-76	395	1.1	94.9	415	1.2
10-12.5	1-29-76	4-7-76	240	1.1	88.6	270	1.2
15-17.5	1-29-76	4-7-76	55	0.2	-	-	-
20-22.5	1-29-76	4-7-76	<50	<0.2	83.9	<60	<0.2
25-27.5	1-29-76	4-7-76	2,130	1.8	82.4	2,590	2.2
29-31.5	1-29-76	4-7-76	<50	0.2	83.1	<60	0.2
34-36.5	1-29-76	4-7-76	<50	<0.2	85.9	<60	<0.2
39-41.5	1-29-76	4-7-76	360	<0.2	84.8	425	<0.2
44-46.5	1-29-76	4-7-76	60	<0.2	82.3	75	<0.2
49-46.5	1-29-76	4-6-76	<50	0.2	83.4	<60	0.2
54-56.5	1-29-76	4-7-76	<50	<0.2	84.8	<60	<0.2
59-60.5	1-29-76	4-7-76	50	<0.2	87.6	60	<0.2

(1) Dry weight values calculated by Barr Engineering

TABLE XV
ANALYTICAL DATA FOR WELL WATER SAMPLES
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Sample	Date Collected	Benzene Extractable, mg/1	Total Dissolved Solids, mg/1	Specific Conductance, μmho @ 25°C	Total Alkalinity, mg/1 as $CaCO_3$	Total Hardness, mg/1 as $CaCO_3$	Phenol, mg/1
City Well #1	4- 1-76	<1	671	790	344	406	<0.002
City Well #2	4- 1-76	<1	468	760	316	414	<0.002
City Well #10	4- 1-76	<1	373	610	340	348	<0.002
#1	4-12-76	<1	515	820	319	405	<0.002
#2	4-28-76	2	683	1200	366	518	<0.002
#5	4- 8-76	1	557	930	410	418	0.153
#6	4- 8-76	14(1)	639	1050	366	472	0.043(1)
#7	4- 6-76	<1	457	740	282	369	<0.002
#8	4- 6-76	<1	611	1000	342	407	<0.002
#9	4- 1-76	4	844	1375	528	272	3.00
#10	4- 1-76	<1	650	1000	472	516	<0.002
Flame Industries	4- 1-76	<1	483	780	340	382	<0.002
Midco Register (formerly - Robinson Rubber)	4-28-76	2(2)	723	1400	454	486	0.170(2)
Relative Standard Deviation (RSD)(3)		-	-	-	2.3%	2.7%	8.7%(4)

< means "less than"

(1) Sample #6 was reanalyzed for benzene extractable and phenol on May 12, 1976, a result of 4 mg/1 benzene extractable and 0.053 mg/1 phenol was obtained.

TABLE XV (CONT.)

(2) Midco Register was reanalyzed for benzene extractable and phenol on May 12, 1976, a result of 1 mg/l benzene extractable and 0.190 mg/l phenol was obtained.

(3) This represents SERCO Laboratories intra-laboratory relative standard deviation for precision. The relative standard deviation represents the quotient of the standard deviation divided by the mean of the data set.

(4) The relative standard deviation of 8.7% for phenol applies to a concentration range of 0.002-0.05 mg/l.

May 13, 1976

TABLE XVI
ANALYTICAL DATA FOR WELL WATER SAMPLES
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

PARAMETER	PRESERVATIVE	BOTTLE TYPE
Benzene Extractable	Frozen at -4°C	Glass
Benzene Extractable	2 ml H_2SO_4 per liter stored at 4°C	Glass
Phenolics (Soil)	Frozen at -4°C	Glass
Phenolics (Water)	5 ml 10% $CuSO_4$/1 + H_3PO_4 to pH 4.0 stored at 4°C	Glass
Solids (Soil)	Frozen at -4°C	Glass
Solids (Water)	Refrigeration at 4°C	Plastic
Specific Conductance	Refrigeration at 4°C	Plastic
Total Alkalinity	Refrigeration at 4°C	Plastic
Total Hardness	Refrigeration at 4°C	Plastic

TABLE XVII
LIST OF ANALYTICAL METHODS
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Parameter	Method	Standard Methods[1]	"EPA"[2]
Benzene Extractable (Soil)[3]	Soxhlet Extraction	P. 412	
Benzene Extractable (Water)[3]	Extraction with Benzene	P. 254	
Phenol	Colorimetric, Chloroform Extraction	P. 501-506	
Percent Solids	Gravimetric	P. 535	
Total Dissolved Solids	Gravimetric	P. 539	
Specific Conductance	Beckman Solu Bridge		P. 275
Total Alkalinity	Potentiometric	P. 52	
Total Hardness	EDTA Titrimetric		P. 68

(1) 13th Edition Standard Methods for the Examination of Water and Wastewaters.

(2) Methods for Chemical Analysis of Water and Wastes, 1974, U.S. EPA.

(3) Standard Methods procedure was modified by the use of benzene for freon as the organic solvent.

May 13, 1976

TABLE XVIII
QUALITY CONTROL DATA FOR SOIL SAMPLES
BARR ENGINEERING COMPANY - ST. LOUIS PARK STUDY
SERCO LABORATORIES JANUARY-APRIL, 1976

Boring Number	Depth, Feet	Benzene Extractable, mg/kg Wet Wt.		Phenol, mg/kg Wet Wt.		Percent Solids	
		Replicate 1	Replicate 2	Replicate 1	Replicate 2	Replicate 1	Replicate 2
1	15	<50	85	0.2	0.5	91.1	90.7
1	55	65	65	<0.2	<0.2	89.6	89.9
3	15	145	80	0.5	0.5	77.0	77.1
3	40	115	100	0.2	0.2	93.0	92.7
4	40	<50	<50	<0.2	0.2	-	-
5	15	960	1110	1.2	1.0	-	-
5	44-45	<50	60	<0.2	<0.2	87.5	88.0
6	40.5-42.5	65	95	1.2	1.1	85.7	86.3
7	5	<50	70	<0.2	<0.2	87.9	87.9
8	44-46	60	75	-	-	-	-
9	10-13	-	-	1.0	0.8	-	-
9	30-31A	135	80	-	-	-	-
10	10-13	74,000	85,100	220	220	33.8	34.9
10	38-40.5B	160	295	2.2	1.6	-	-
10	58-60.5	-	-	-	-	91.9	91.8
11	10-13	255	255	0.2	0.2	-	-

TABLE XVIII (CONT.)

Boring Number	Depth, Feet	Benzene Extractable, mg/kg Wet Wt.		Phenol, mg/kg Wet Wt.		Percent Solids	
		Replicate 1	Replicate 2	Replicate 1	Replicate 2	Replicate 1	Replicate 2
12	5-7	32,300	29,400	9.6	9.6	23.1	22.2
12	44-46	215	245	0.2	<0.2	86.7	86.3
12	49-51	55	100	<0.2	<0.2	85.6	85.6
14	20-22.5	<50	<50	<0.2	<0.2	83.9	85.0

<means "less than"

May 13, 1976

APPENDIX I

Laboratory Procedures for Phenol and Benzene Extractables

Mar. 4, 1976

REPORT OF REVIEW OF LABORATORY PROCEDURES
PHENOL AND EXTRACTABLES
ST. LOUIS PARK
FOR BARR ENGINEERING COMPANY
FEBRUARY, 1976

I. Introduction

Four core samples collected by Barr Engineering Company with reference to the St. Louis Park Soil and Groundwater Study were delivered to SERCO Laboratories on January 21, 1976 and kept frozen at approximately -10°C until analysis was begun. The samples were identified as Special Sample No. 1, 2, 3 and 4. Approximately 500 to 1000 grams of sample were received from each sampling site. The samples were analyzed for total extractable organic matter and phenols. The purpose of this analysis was to determine the gross amount of contamination and its distribution throughout the soil. Before a quantitative identification of all core samples collected can be made for total extractable organic matter and phenols, the analytical procedures must be refined to accomodate the complex sample matrices. This is the reason for the work contained in the report.

II. Phenol Analysis

All phenol analyses contained in this report were performed according to the procedure listed in the 13th Edition of Standard Methods for the Examination of Water and Wastewater, pages 501 through 506.

Four samples were analyzed for the determination of phenol on February 2. The same four samples were re-run on February 10 (See Table I). The appropriate sample portion required for the analysis was obtained by cutting out a subsection from the core approximately four centimeters in width. The sample was then obtained from the center of the subsection using a stainless steel spatula. The data in Table I demonstrates a magnitude of order variation for sample #2. The factors responsible for the variation were dependent upon the date analyzed, the weight of the sample used and the concentration of the phenolic material in the sample. As indicated in Table I the four samples were initially analyzed on February 2, 1976 and again run on February 10, 1976. Between February 2 and February 10 the samples were stored at 4°C. Due to the unstable nature of phenols and benzene extractables the samples may have been susceptable to biological degradation or oxidation resulting in some variation of the data. It was also questionable if the subsection sampling technique yeilded a representative sample for analysis. A homogenous particle size could not be obtained using this technique and the procedure did not adequately represent possible concentration gradients occuring throughout the core. The magnitude of variation in sample #2 may also have been dependent on the concentration of phenol as the detection limit was 0.1 mg/kg wet weight basis.

Due to the unacceptable variation of the data in Table I, modifications in the sampling technique, amount of sample used for the analysis and the date duplicates were analyzed were incorporated to enhance the precision of the analysis. Table II demonstrates a higher degree of precision throughout a wide concentration range by implementing a smaller sample size from 10 grams to 5 grams for samples containing concentration of phenol less than 10 mg/kg wet weight and a change of sample size from 2 grams to 0.5 gram for samples containing a phenolic concentration in excess of 200 mg/kg wet weight. Also, it was found that the reduced sample size minimized carryover of interferring substances, such as tars and oils. The replicate samples in Table II were analyzed on the same day as oposed to an eight-day time interval between the analysis for the data given in Table I. The samples analyzed in Table II were obtained from the core by using a quartering sample technique. In quartering, the soil is spread uniformly over a sheet of aluminum foil, mixed and divided into four equal portions. Two of the portions are randomly discarded and the remaining portion is mixed together, spread out again and reduced to half by the same procedure. This process is repeated until a sample of required bulk is obtained. All mixing was accomplished by the use of a stainless steel spatula. The data obtained in this manner was reproducible within 10 to 20 percent.

As indicated in Table II, replicate analyses were also conducted on sample No. 4 to determine the possible interference due to the high concentrations of oils and tars in the more polluted samples. Tar and oil will be carried over in the distillation and produce a negative bias in the colorimetric determination of phenol. The tar and oil content of samples 4C and 4D was removed prior to distillation by incorporating the procedure listed on page 502 of Standard Methods. Accordingly, the samples were extracted in an alkaline medium with carbon tetrachloride. The oil or tar containing layer was discarded and any excess of carbon tetrachloride in the aqueous layer removed by warming the sample on a warm bath before proceeding with the distillation step. The analysis of these samples revealed no significant change in the magnitude of phenolics determined, but did yield a wider variation or less precision (400 mg/kg wet weight and 305 mg/kg wet weight) than for the analysis of the same sample without pretreatment as shown for samples 4A and 4B (360 mg/kg wet weight and 340 mg/kg wet weight). It is concluded that a quantitative determination of phenols on the core samples can be accomplished without removal of tar and oil. It will be important to select a sample size for the analyses which will contain no more than 100 micrograms of phenol. It is understood that all samples will be received at SERCO Laboratories in a frozen state. Samples will be melted and analyzed immediately to minimize any degradation of the sample due to oxidation or microbiological activity. It will also be important to incorporate the quartering sample technique for all analyses so as to insure a representative sample is obtained form the core.

III. Total Extractable Organic Matter Analysis

In order to get a quantitative estimation of the total extractable organic matter which would be primarily petroleum derived, benzene and xylene were selected as possible solvents. Outside of the solvents used, the analytical procedure is the same as the soxhlet extraction procedure given on page 409 of Standard Methods. Again, samples were run in duplicate to determine the precision of the method and sampling procedures. As indicated in Table III, the subsection and sampling technique again yielded erratic results in an order of magnitude variability. The lack of precision of the data in Table III may be partly attributed to the lag time between analysis of the replicates. The first samples were analyzed on February 2, 1976 and the replicate samples for the benzene extractables analyzed on February 12, 1976. The samples when extracted with xylene yielded an acceptable agreement with the benzene extractables. However, because of the higher boiling point of xylene, 140°C, benzene was selected as the solvent for all extractions.

Because of the gross content of organic extractable materials in some of the sample matrices, in excess of 30,000 mg/kg wet weight, an optimum reflux time had to be determined to assure quantitative recovery of the extractable organic material. Table IV indicates an enhancement of the precision with the utilization of the quartering sampling technique and in excess of 98% recovery of the benzene extractables with a four-hour reflux period. As indicated in Table IV, 10 grams of sample No. 4 was refluxed for the standard four-hour time interval. Fresh solvent was then used for an additional four-hour reflux on the sample and the percent recovery of the first four hour reflux calculated. A quantitative estimation of benzene extractables in the samples will be obtained if implementation of the quartering sampling technique is used and all samples are analyzed as soon as possible after melting. For grossly polluted samples, the sample size should not exceed 10 grams in order to avoid incomplete dissolution of benzene extractables in the four hour reflux period.

IV. Quality Control

It is recommended that 10% of all samples analyzed for benzene extractables and phenols be run in duplicate. As an additional quality control feature it may be desireable to spike 10% of all samples for phenol to determine the extent of interferences caused by the sample matrix.

V. Summary

In summary, by minimizing the time when the sample has been melted until the analysis has been completed, and optimizing the sample weight used for each particular analysis and utilizing the quartering sample technique, viable data reflecting the concentrations of benzene extractables and phenols throughout the soil should be obtained.

The report and the laboratory analyses described herein have been performed by myself or under my direct supervision.

Submitted by,

SERCO LABORATORIES

William A. O'Connor

William A. O'Connor, Chemist
Director of Laboratory Services

March 4, 1976

TABLE I

PHENOL DATA USING SUBSECTION AND SAMPLE TECHNIQUE
CORE SAMPLES - ST. LOUIS PARK
BARR ENGINEERING COMPANY
MINNEAPOLIS, MINNESOTA
SERCO LABORATORIES FEBRUARY, 1976

Sample	Date Analyzed	Weight of Sample, gram	mg/kg, wet weight
1	2-2-76	10	2.3
1	2-10-76	10	3.5
2	2-2-76	10	0.3
2	2-10-76	10	3.0
3	2-2-76	2	300
3	2-10-76	2	512
3	2-10-76	2	350
4	2-2-76	2	200
4	2-10-76	2	300

TABLE II

PHENOL DATA USING QUARTERING SAMPLE TECHNIQUE
CORE SAMPLES - ST. LOUIS PARK
BARR ENGINEERING COMPANY
MINNEAPOLIS, MINNESOTA
SERCO LABORATORIES FEBRUARY, 1976

Sample	Date Analyzed	Weight of Sample, gram	mg/kg, wet weight
1	2-25-76	5.0	1.2
1	2-25-76	4.1	0.9
2	2-25-76	4.0	9.2
2	2-25-76	4.0	7.8
4A	2-24-76	0.44	360
4B	2-24-76	0.32	340
4C	2-24-76	0.44	400*
4D	2-24-76	0.53	305*

* Extracted with carbon tetrachloride prior to distillation.

TABLE III

BENZENE OR XYLENE EXTRACTABLES
USING SUBSECTION AND SAMPLING TECHNIQUE
CORE SAMPLES - ST. LOUIS PARK
BARR ENGINEERING COMPANY
MINNEAPOLIS, MINNESOTA
SERCO LABORATORIES FEBRUARY, 1976

Parameter	Date Analyzed	Weight of Sample, gram	Benzene Extractable wet weight, mg/kg	Xylene Extractable wet weight, mg/kg
1	2-2-76	20	5955	-
1	2-12-76	20	590	-
1	2-13-76	20	-	420
2	2-2-76	20	5390	-
2	2-12-76	20	735	-
2	2-13-76	20	-	685
3	2-2-76	20	36,280	-
3	2-12-76	20	32,245	-
3	2-13-76	20	-	35,000
4	2-2-76	20	12,560	-
4	2-12-76	20	29,035	-
4	2-13-76	20	-	18,570

TABLE IV

RECOVERY OF BENZENE EXTRACTABLES
USING QUARTERING SAMPLING TECHNIQUE
CORE SAMPLES - ST. LOUIS PARK
BARR ENGINEERING COMPANY
MINNEAPOLIS, MINNESOTA
SERCO LABORATORIES FEBRUARY, 1976

Sample	Date Analyzed	Weight of Sample, gram	First 4-hour Reflux Benzene Extractable mg/kg wet weight	Second 4-hour Reflux Benzene Extractable mg/kg wet weight	Percen Recover
4	2-24-76	10	29,620	280	99.1
4	2-24-76	10	25,450	430	98.3

APPENDIX II

Evaluation of Procedures for
Reporting Percent Solids

M E M O R A N D U M

TO: Barr Engineering Company - Allan Gebhard

FROM: SERCO Laboratories - William A. O'Connor

SUBJECT: Evaluation of Analytical Procedures to be used for Reporting Percent Solids on Soil Samples collected for the St. Louis Park Groundwater Study

DATE: April 6, 1976

The purpose of this memorandum is to review the analytical procedures which have been evaluated at SERCO Laboratories for the determination of percent solids on the soil samples, submitted by Barr Engineering Company and collected at St. Louis Park. Comparability data was obtained on soil samples dried in air at room temperature and in an oven set at 105°C. Analytical data for this analysis is given in Table I.

Analytical Procedures

Oven Drying Procedure

All samples analyzed were received at SERCO Laboratories frozen. The samples were thawed at room temperature, coned and quartered and a representative sample obtained for the percent solids determination. The sample was then placed in an evaporating dish and weighed. The dish was placed in an oven set at 105°C and dried to a constant weight. The sample was then cooled in a desiccator and weighed.

Air Drying Procedure

A representative soil sample was obtained as specified in the oven drying procedure and placed into an evaporating dish and weighed. The sample was allowed to dry at room temperature for a 24-hour period. This drying interval was sufficeint to obtain a constant weight on all soil types. After the 24-hour period, the sample was again weighed.

Conclusions:

As indicated in Table I, a wide variety of sample types were analyzed including very fine sand, clays and contaminated peat samples. The results between the oven dried and air dried procedures for all sample types show good comparability, a standard deviation of ±2.1. It is recommended that all soil samples to be analyzed for percent solids be reported according to the oven dried procedure as there seems to be no significant loss of volatile organic compounds using this procedure.

TABLE I

BARR ENGINEERING COMPANY
ST. LOUIS PARK GROUNDWATER STUDY
EVALUATION OF ANALYTICAL PROCEDURES
USED FOR REPORTING PERCENT SOLIDS

SERCO LABORATORIES

SAMPLE SITE	SAMPLE TYPE	PERCENT SOLIDS OVEN DRIED - 105°C, % SOLIDS	PERCENT SOLIDS AIR DRIED, % SOLIDS
1525	Coarse sand	80.8	82.3
1526	Fine sand	82.2	84.9
1527	Fine sand	87.8	87.3
1528	Clay	84.7	87.1
1529	Coarse sand	88.8	85.1
2017	Gravel - brown contaminated	88.0	88.0
2022	Peat - black	20.0	21.9
2024	Peat - black	45.8	45.6

APPENDIX C

LABORATORY REPORT

MIDWEST RESEARCH INSTITUTE

KANSAS CITY, MISSOURI

ANALYSIS OF POLYNUCLEAR ORGANIC MATERIALS (POMs) IN SOIL AND WATER--PHASE I

by

Clarence L. Haile

FINAL REPORT
May 5, 1976

MRI Project No. 5-1492-C

For

SERCO Laboratory, Inc.
2982 North Cleveland Avenue
Roseville, Minnesota 55113

MIDWEST RESEARCH INSTITUTE 425 VOLKER BOULEVARD, KANSAS CITY, MISSOURI 64110 • 816 561-0202

PREFACE

This report presents the results of the Phase I study of a project entitled, "Analysis of Polynuclear Organic Material (POMs) in Soil and Water," performed by Midwest Research Institute (MRI) for SERCO Laboratory, Inc. The MRI Project No. was 5-1492-C.

This study was conducted during the period March 27 to April 23, 1976. Dr. Clarence Haile, Project Leader, was assisted by Mr. P. Cramer and Ms. M. Woodfin, Junior Chemists. The project was under the general analytical supervision of Dr. J. Spigarelli, Head, Analytical Chemistry Section. Dr. Haile prepared this final report.

Approved for:

MIDWEST RESEARCH INSTITUTE

F. I. Metz, Assistant Director
Physical Sciences Division

May 5, 1976

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SUMMARY

Eleven soil samples, provided by SERCO Laboratory, Inc., were examined for polynuclear organic materials (POMs). Soils were extracted with cyclohexane and the extracts screened by thin-layer chromatography (TLC) on silica gel. Development with 1.5:1 (v/v) benzene-cyclohexane and visualization under long ultraviolet light indicated considerable POM levels in several samples--notably from shallow strata of wells Nos. 5 and 9A. TLC plates for five soil extracts were scraped and reextracted for gas chromatographic examination. Anthracene, 3-methylcholanthrene, and 3,4,5,6-dibenzcarbazole were not identified in any extract. Benz[c]-phenanthrene was noted in two of five extracts at levels slightly exceeding the detection limit. Chrysene was found in the 47.5 to 49 ft strata soil from well No. 9A at 474.5 μg/g dry soil and benz[a]pyrene was noted in the same soil at 6.9 μg/g dry soil. Several unassigned peaks on the GC traces indicated notable quantities of other POMs not identified.

I. INTRODUCTION

The objective of this project is to provide SERCO Laboratory, Inc., with analytical services to determine levels of polynuclear organic materials (POMs) in soil and water extracts. Under Phase I of this project 11 soil samples were provided by SERCO for analysis.

The analytical procedures utilized in and results of Midwest Research Institute's (MRI) analysis of these soils are described in subsequent sections of this report. Appended to the report are thin-layer and gas chromatograms supporting the results reported.

II. ANALYTICAL PROCEDURES

This section describes the samples examined in addition to procedures utilized for sample extraction, extract screening by thin-layer chromatography (TLC), and gas chromatographic (GC) determination of POMs in selected extracts.

A. Samples

Eleven soil samples were received from SERCO on March 12, 1976. The samples were stored in a dark cold room (temperature ca. 3°C). Throughout the course of the study excessive exposure of the samples and extracts to heat and light was avoided. The soil samples, recovered from drilled wells, are described in Table 1 along with MRI's sample codes.

The moisture content of the soils was determined to facilitate comparison of levels of contamination. Two 1 g aliquots of each soil were weighed, heated to 110°C overnight, and reweighed to allow determination of water content. The results of the moisture test are also shown in Table 1.

B. Sample Extraction

Aliquots of most soils equivalent to 20 g dry weight were extracted. Due to their high moisture contents, only 10.9 and 14.8 g (dry weight basis) of SS-109-1 and SS-111-1, respectively, were extracted. Each soil aliquot was thoroughly mixed with 25 g of anhydrous Na_2SO_4 (prewashed with hexane) to form a dry, free-flowing mass before extracting at least 6 hr with cyclohexane in all glass Soxhlet extractors. Extracts were evaporated to 1 ml by means of a purified nitrogen stream.

TABLE 1

SOIL SAMPLES FOR POM ANALYSIS

Sample No.	Well No.	Depth (ft)	% Water
SS-105-1	5	5	13.5
SS-105-2	5	15	10.6
SS-105-3	5	34-35	4.8
SS-109-1	9	10-13	69.3
SS-109A-1	9A	30-33	13.9
SS-109A-2	9A	47.5-49	14.4
SS-109B-1	9B	30-33	24.9
SS-109B-2	9B	47-49.5	17.7
SS-111-1	11	5-8	66.1
SS-111-2	11	29-31.5	12.0
SS-111-3	11	39-41.5	10.5

C. Extract Screening

The extracts were streaked on 20 x 20 cm glass plates of silica gel (Quantum LQ plates). Plates were developed with 1.5:1 (v/v) benzene-cyclohexane and then visualized under long ultraviolet light. Bands visible were marked by scribing and the plates were photocopied. The sample regions between the origin and solvent front were scraped off and extracted with 20 ml cyclohexane. Plate extracts were evaporated to 1 ml by means of a purified nitrogen stream.

D. Extract Analysis

Extracts from TLC plates of five soil extracts were examined for POMs by gas chromatography. Extracts were chromatographed on a 1.8 m x 2 mm glass column of 3% Dexsil 300 GC on 100/120 mesh Supelcoport held at 280°C and eluted with 30 ml/min purified nitrogen into an electron capture detector. Chromatograms were compared with those for a mixed standard containing benz[c]phenanthrene, chrysene, 7,12-dimethylbenz[a]anthracene, benz[a]pyrene, 3-methylcholanthrene, and 3,4,5,6-dibenz-carbazole. Anthracene was not quantitated as it was not identified in the samples examined. Chromatograms of extraction and TLC blanks showed no peaks. An extraction blank spiked with 25 μg benz[a]pyrene (to simulate 1.25 μg/g in 20 g soil) was also screened by TLC and quantitated by GC. Recovery was 69%.

III. RESULTS

A. Thin-Layer Chromatographic Screening

A summary of the results of TLC screening of the soil extracts for POMs is contained in Table 2. Photo reproductions of the plates are shown in Appendix A. Band locations were based solely on visualization under long ultraviolet light (by fluorescence) except a few of the yellow bands which were also visible under white light. All sample extracts contained materials which fluoresce under long ultraviolet. Four samples, SS-105-3, SS-109A-1, SS-109B-2, and SS-111-3, contained little fluorescent material while two, SS-105-1 and SS-109A-2, showed an abundance of fluorescent material. As a result of this screening, chromatographed extracts of five samples, SS-105-1, SS-105-2, SS-109A-2, SS-109B-1, and SS-111-2 were selected for GC examination.

B. Gas Chromatographic Analysis

A summary of the results of GC examination of five soil extracts is contained in Table 3. Concentrations are based on dry soil. Reproductions of the chromatograms are shown in Appendix B. Peak identities were based solely on retention times. Anthracene was not identified in the extracts and, since it tends to be obscured by solvent peak tailing, was excluded from the mixed standard. Two compounds in the mixed standard, 3-methylcholanthrene and 3,4,5,6-dibenzcarbazole, were also not identified in the extracts at detection limits of 0.03 μg/g and 0.3 μg/g dry soil, respectively. Benz[c]phenanthrene was noted in two of five extracts at levels slightly exceeding the detection limit. Chrysene, undetected in two extracts, was found in SS-109A-2 at 474.5 μg/g. Benz[a]pyrene was also found in SS-109A-2 at 6.9 μg/g and in SS-109B-1 slightly exceeding the detection limit.

Examination of the chromatograms (see Appendix B), especially for SS-109A2 and SS-109B-1, show many peaks whose identities could not be assigned with the POM standards available. Additional GC and GC/MS examination are required for their identification.

TABLE 2

SUMMARY OF TLC SCREENING

Sample/R_f Decade	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Anthracene						0.58 V				
Chrysene						0.58 V				
Benz[a]pyrene						0.57 Y				
SS-105-1	0.05 1B	0.13 Fb	0.21 G		0.48 Y		0.66 B			
SS-105-2	0.02 B-V 0.08 1B	0.18 1B	0.25 Y	0.36 1B	0.49 B	0.56 V				
SS-105-3						0.59 fB	0.69 fB			
SS-109-1	0.02 P 0.06 Y	0.12 P				0.53 1B	0.63 Y			
SS-109A-1	0.03 bB	0.18 fB	0.29fB					0.74 fB		
SS-109A-2	0.03 B	0.12 Y 0.16 G	0.23 G	0.38 G		0.59 Y	0.67 V			
SS-109B-1		0.13 G	0.23 B	0.35 B	0.47 Br	0.53 Y	0.63 B			
SS-109B-2						0.54 B				
SS-111-1	0.02 Y-Br 0.08 V	0.10 Y				0.56 B				
SS-111-2	0.03 V 0.08 B		0.22 Y		0.48 Y	0.58 V				
SS-111-3	0.02 fG 0.09 fB	0.16 fB			0.49 fG	0.56 fG				

Legend: B - blue; G - green; P - pink; Br - brown; V - violet; Y - yellow; f - faint; 1 - light; b - bright.

TABLE 3

SUMMARY OF GC EXAMINATION

Sample No.	Benz[c]phenanthrene (µg/g)	Chrysene (µg/g)	Benz[a]pyrene (µg/g)
SS-105-1	< 0.2	10.0	< 0.2
SS-105-2	< 0.2	< 3.2	< 0.2
SS-109A-2	0.25	474.5	6.9
SS-109B-1	0.36	49.0	0.93
SS-111-2	< 0.2	< 3.2	< 0.2

APPENDIX A

THIN-LAYER CHROMATOGRAPHIC SCREENING

The figures of this section are photo reproductions of the TLC plates utilized for soil extract screening for POMs. Band locations were noted by visualization under long ultraviolet.

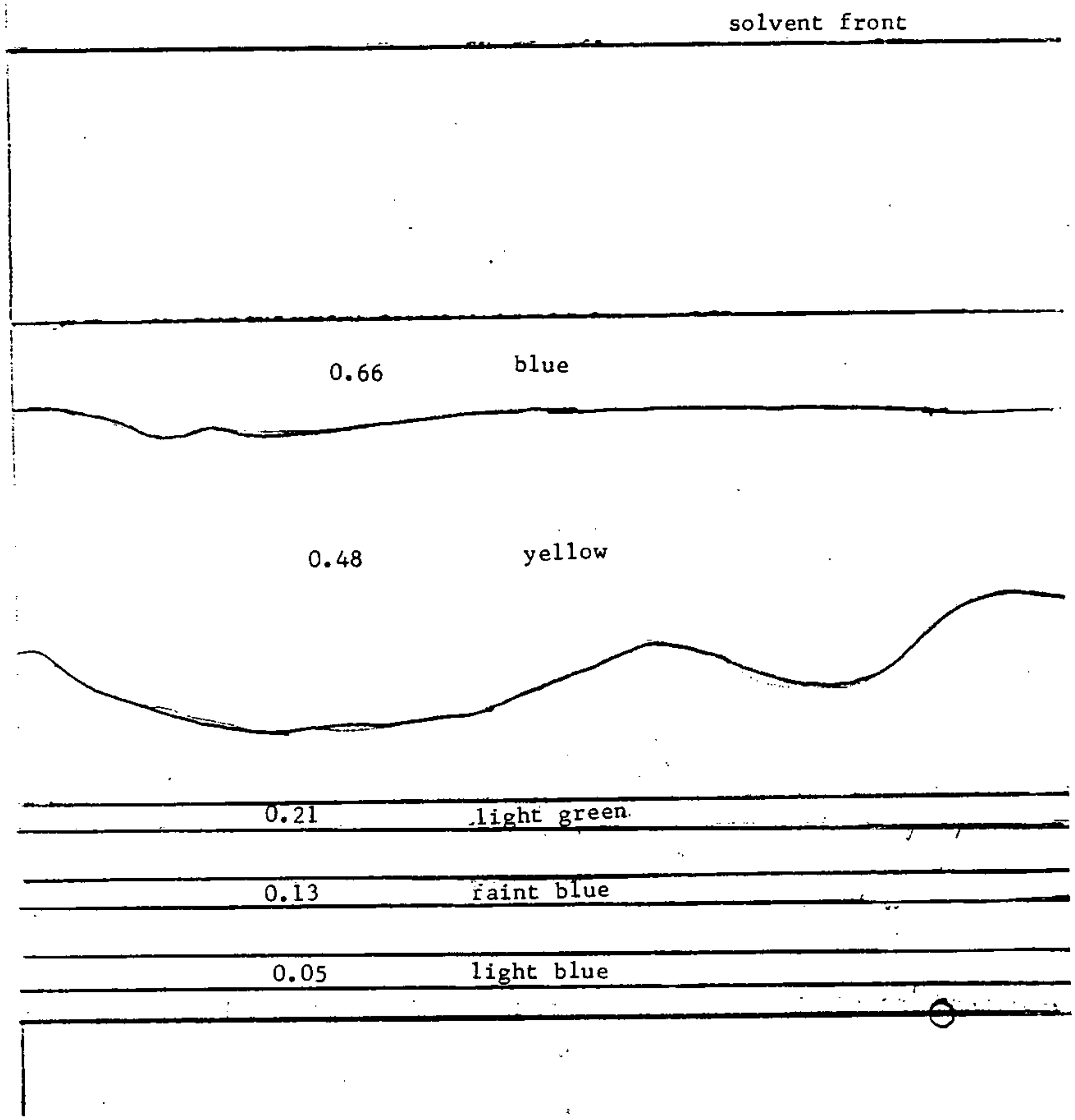


Figure A-1 - TLC of Sample SS-105-1

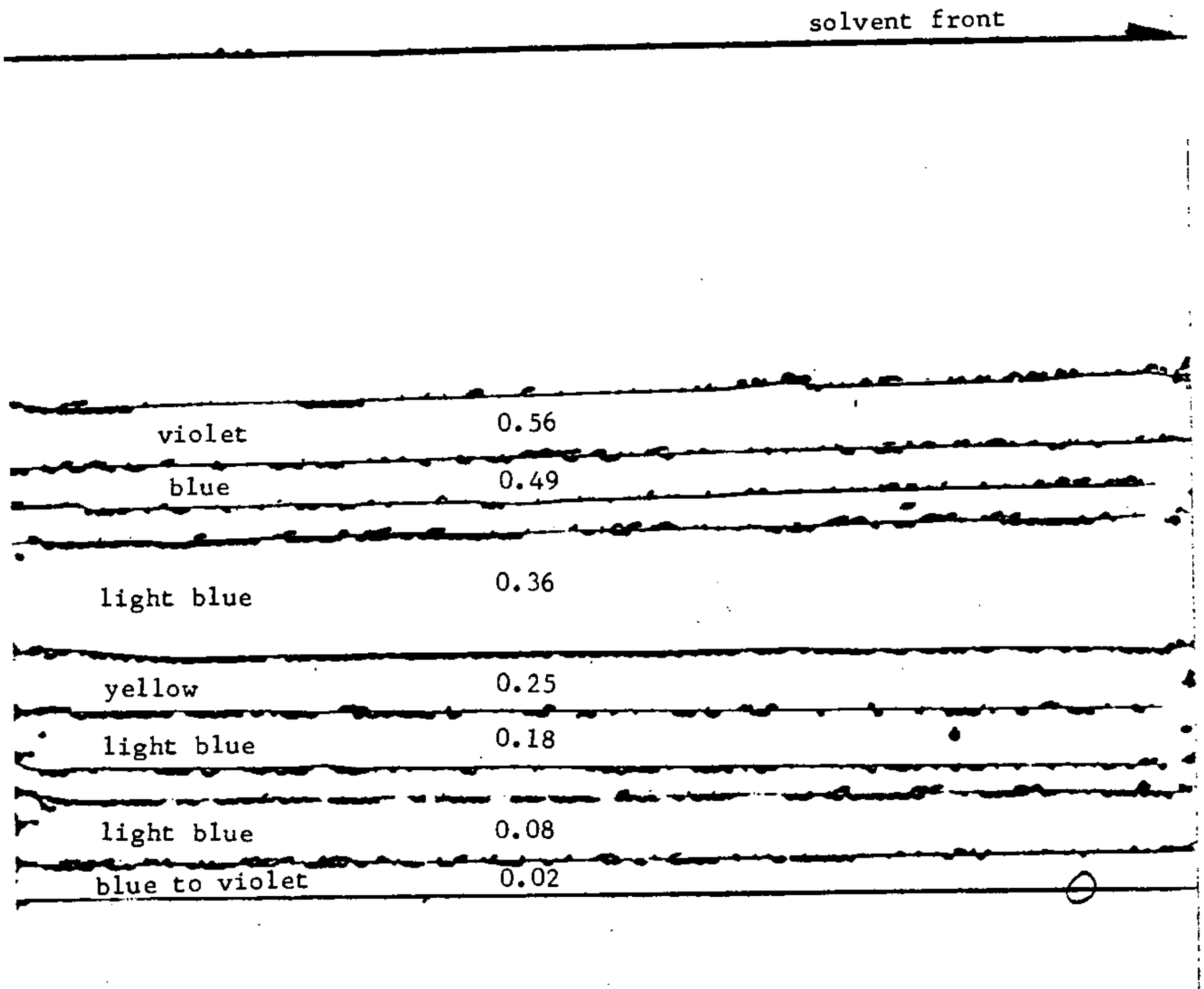


Figure A-2 - TLC of Sample SS-105-2

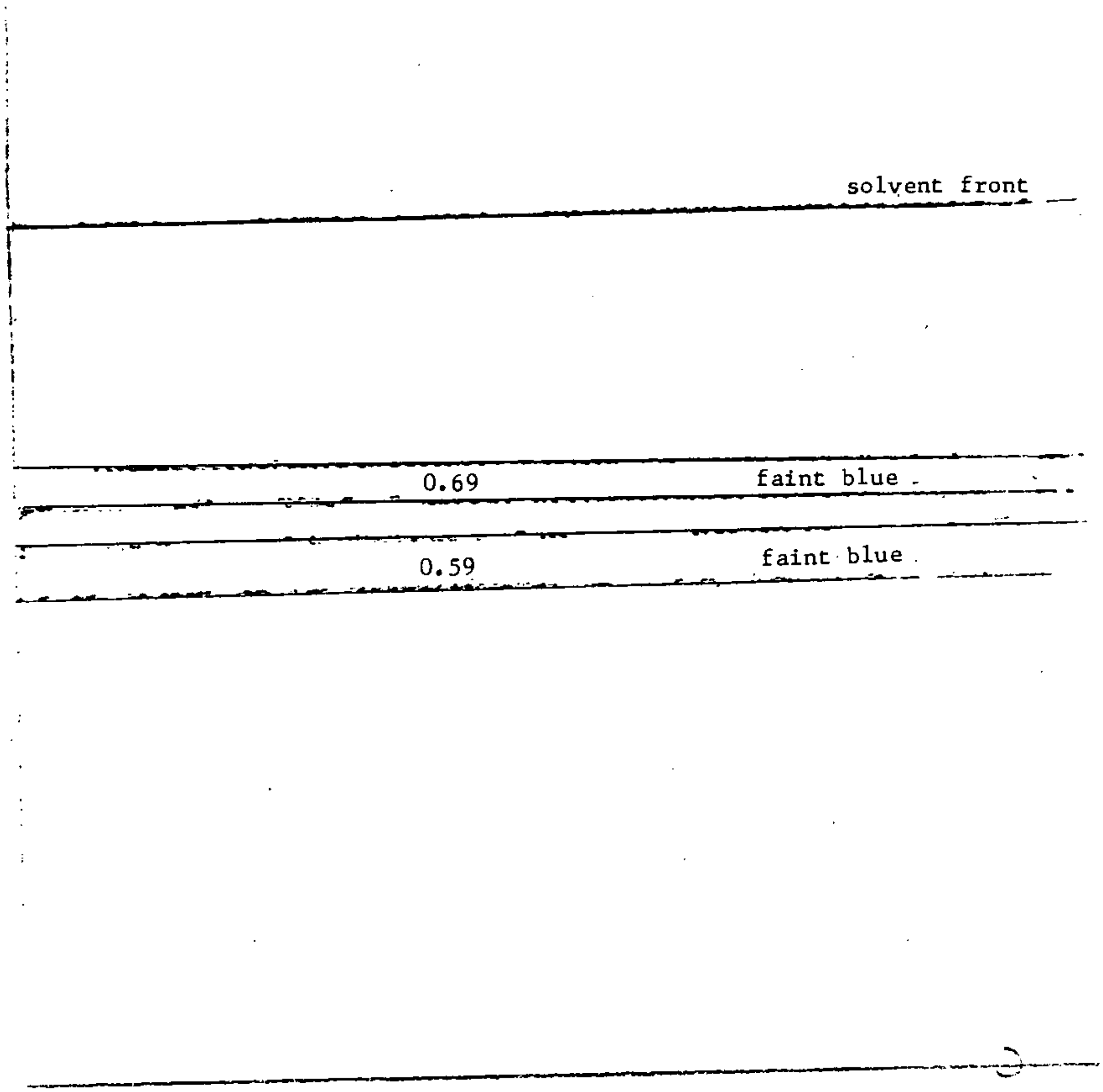


Figure A-3 - TLC of Sample SS-105-3

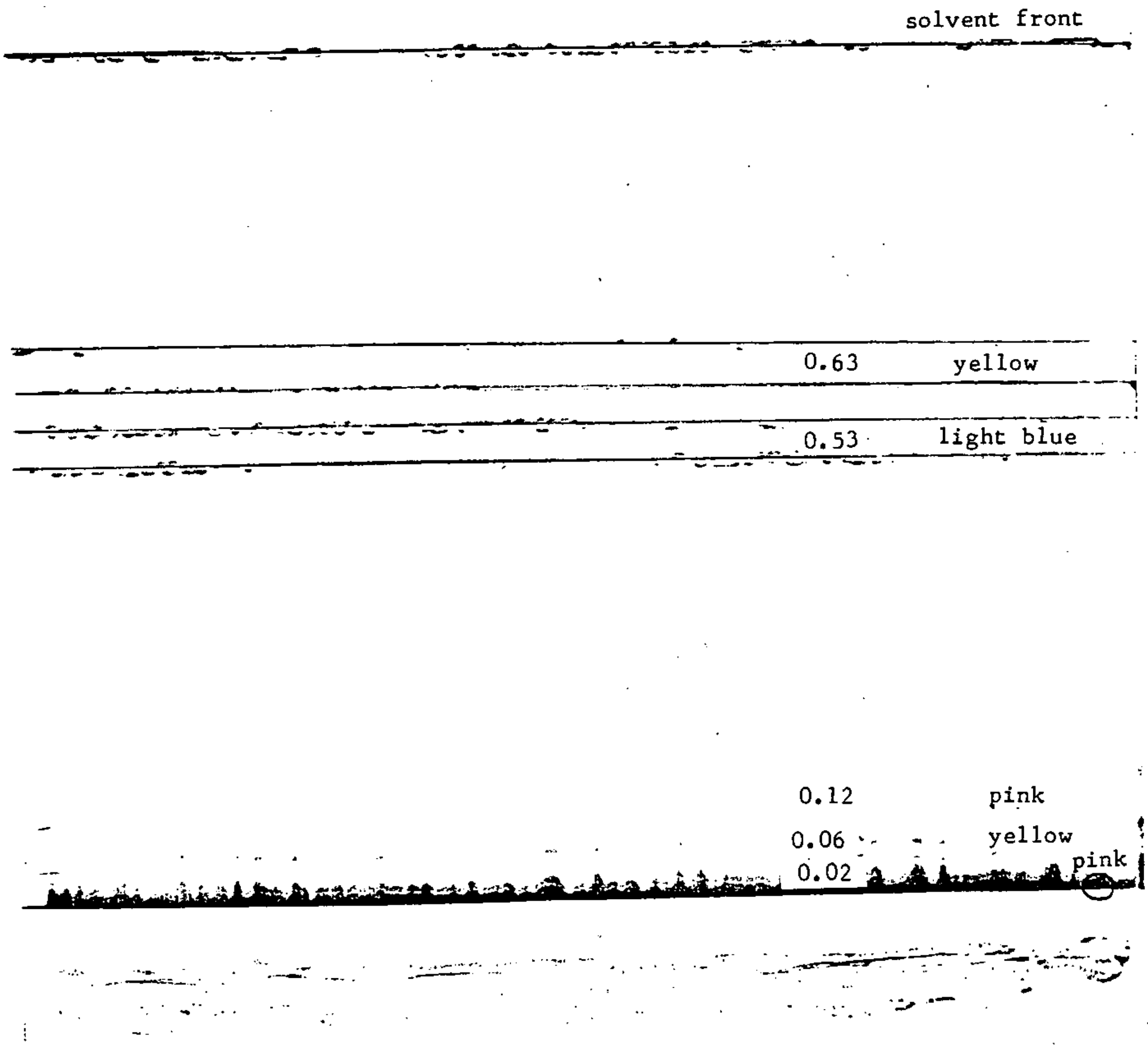


Figure A-4 - TLC of Sample SS-109-1

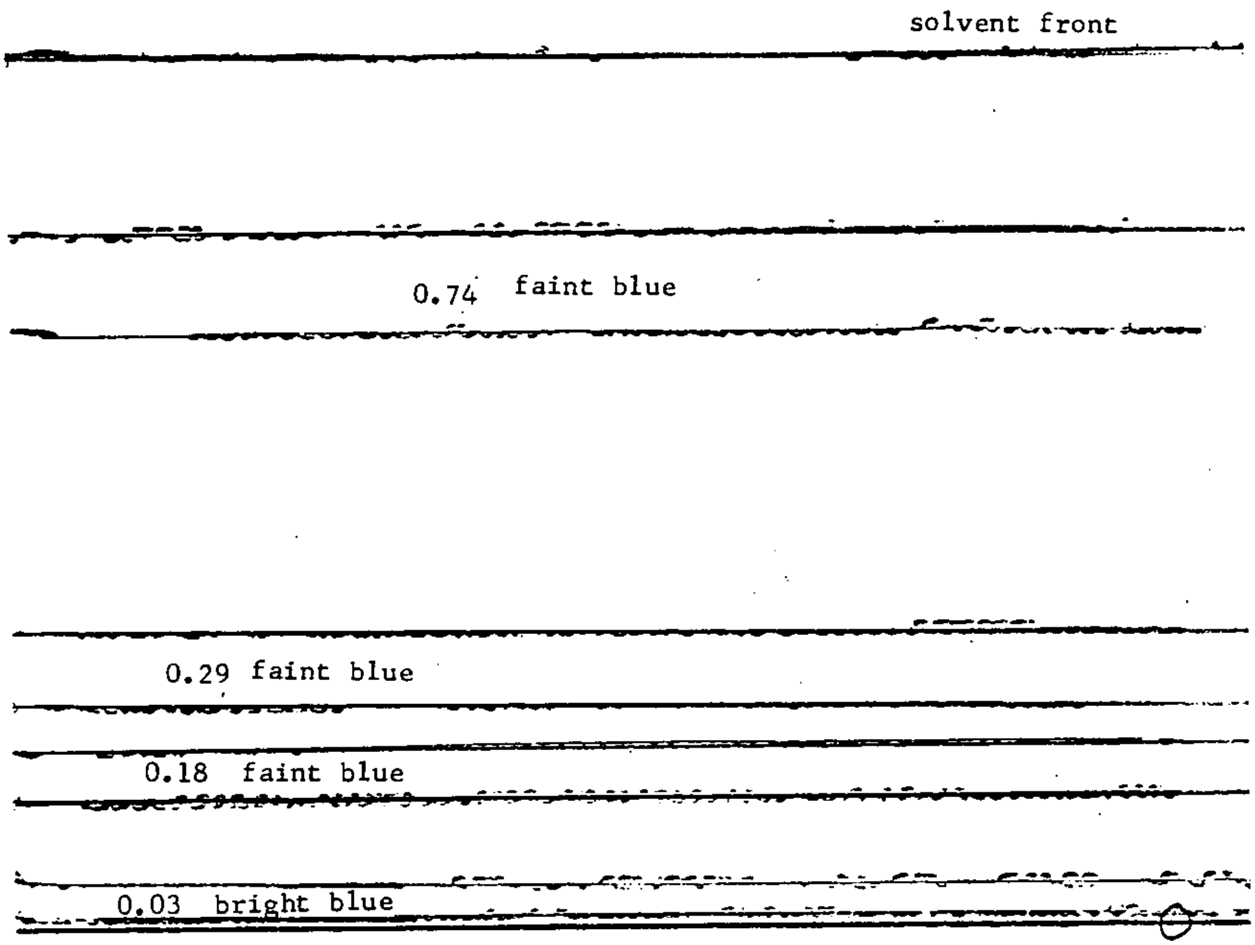


Figure A-5 - TLC of Sample SS-109A-1

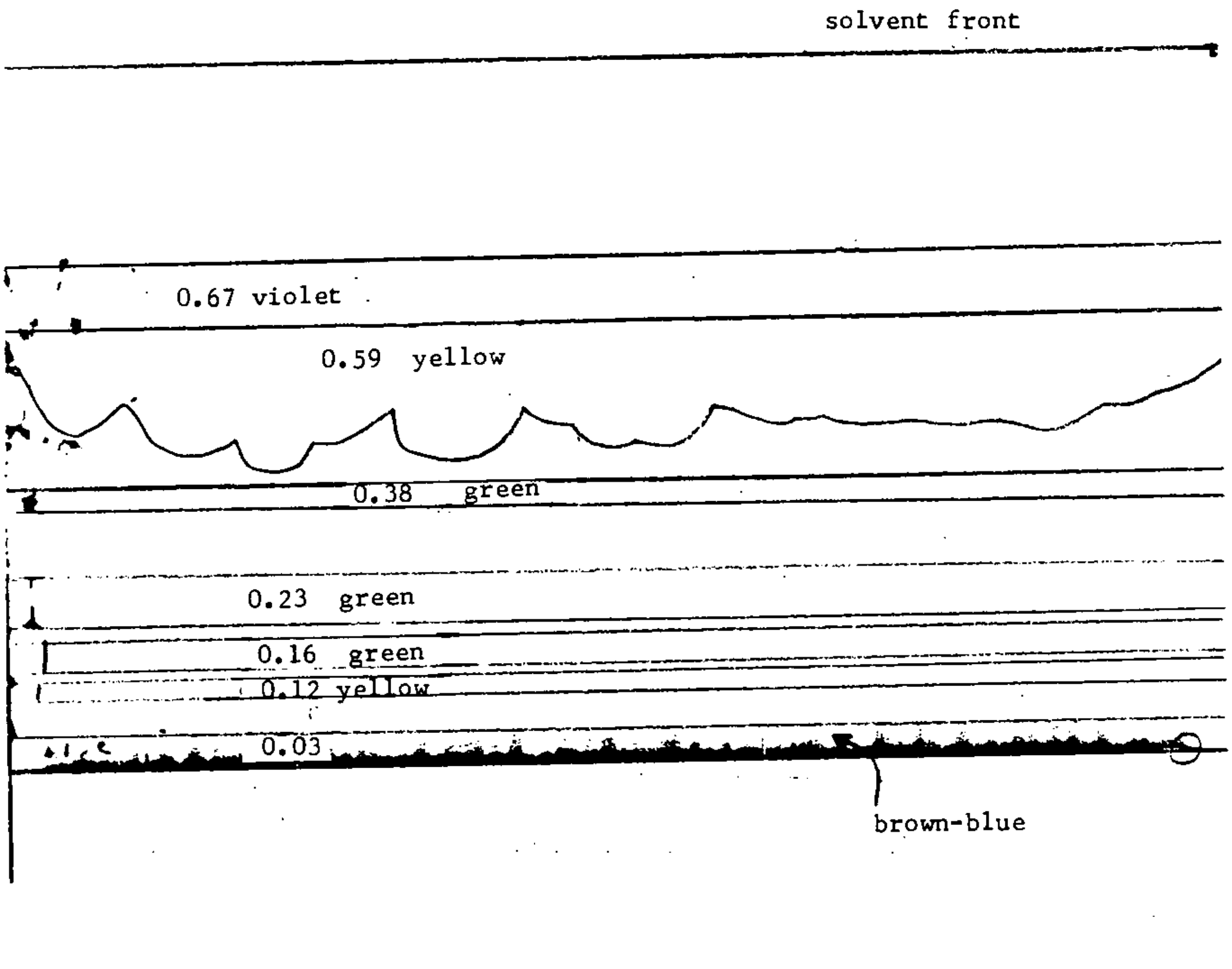


Figure A-6 - TLC of Sample SS-109A-2

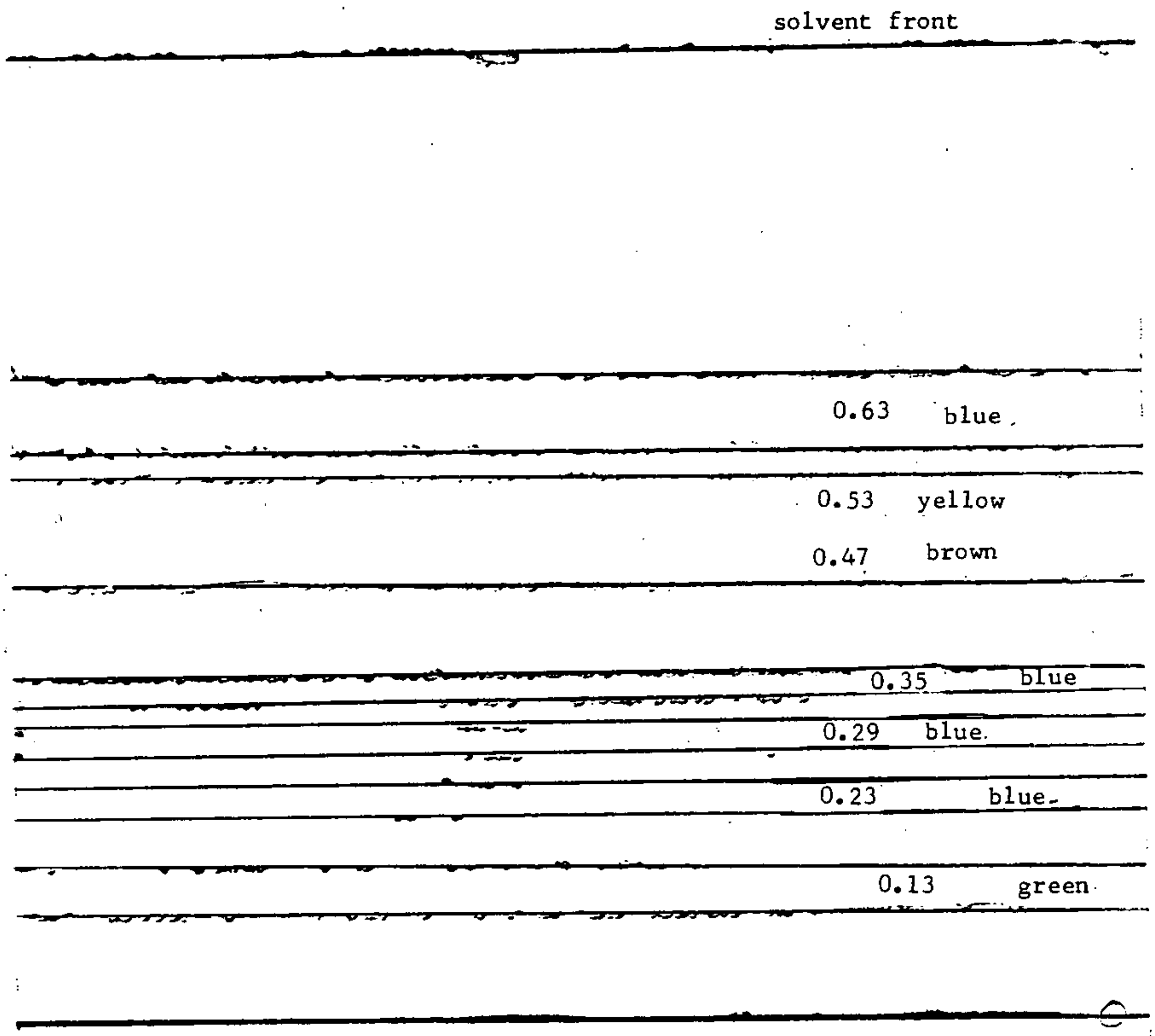


Figure A-7 - TLC of Sample SS-109B-1

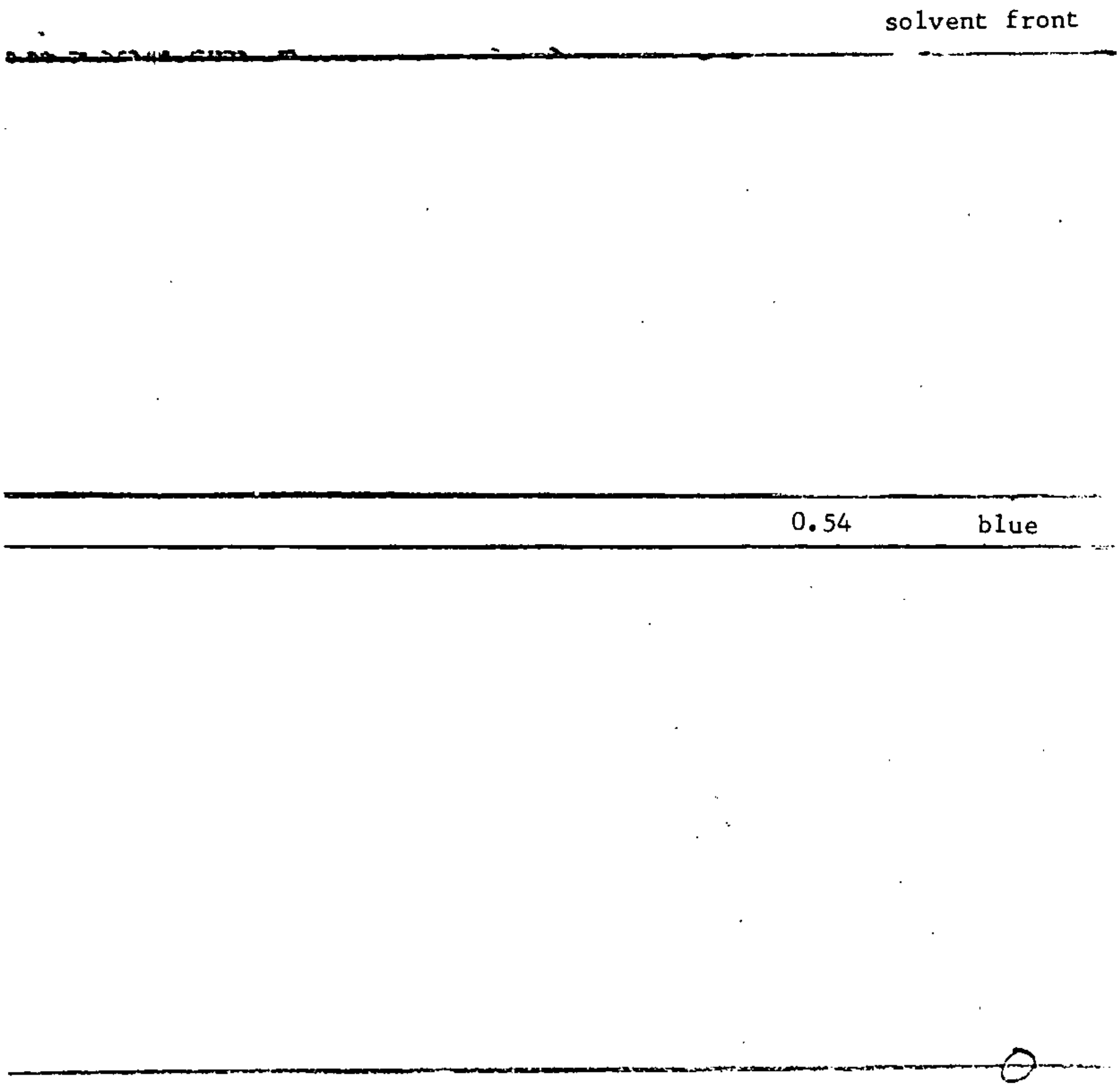


Figure A-8 - TLC of Sample 109B-2

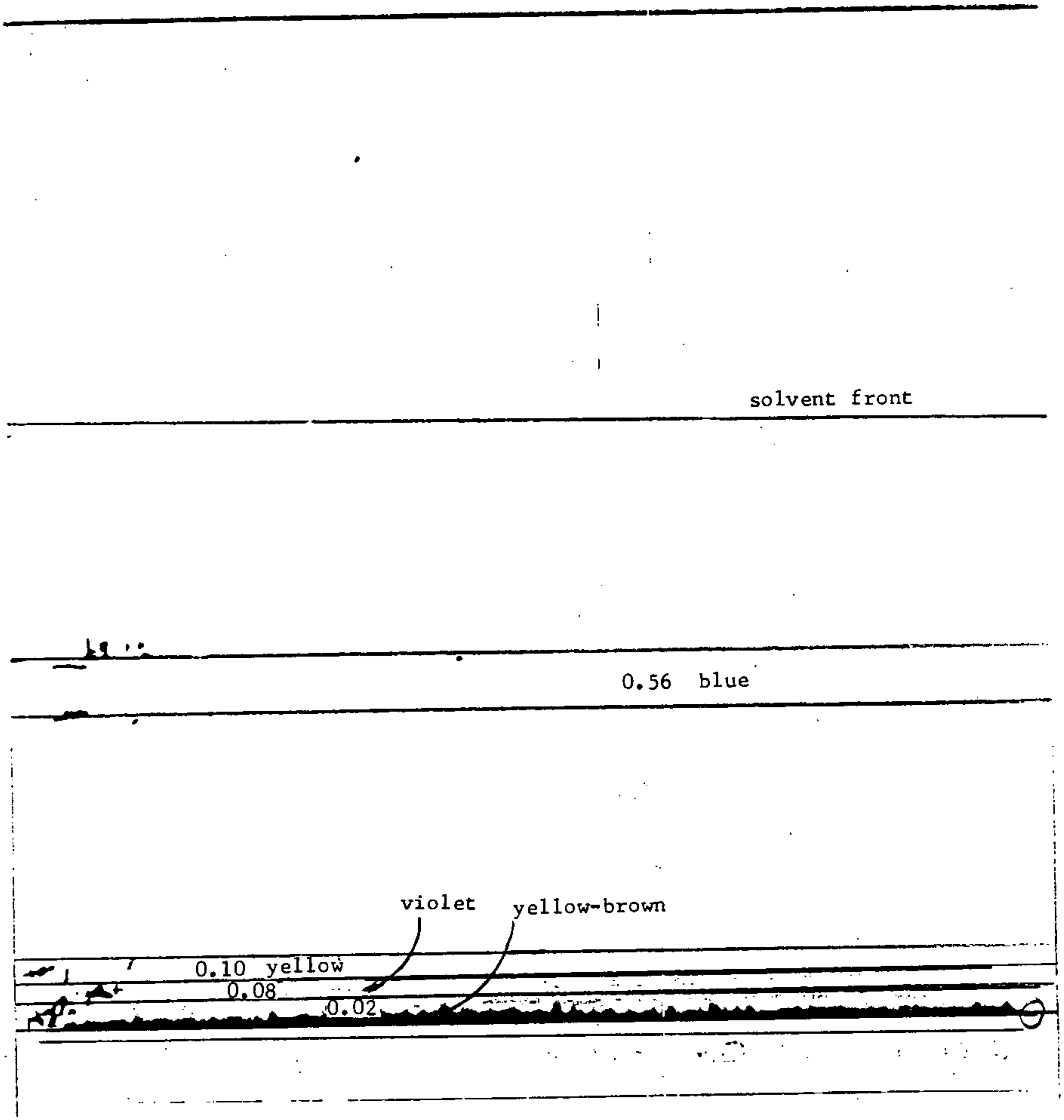


Figure A-9 - TLC of Sample SS-111-1

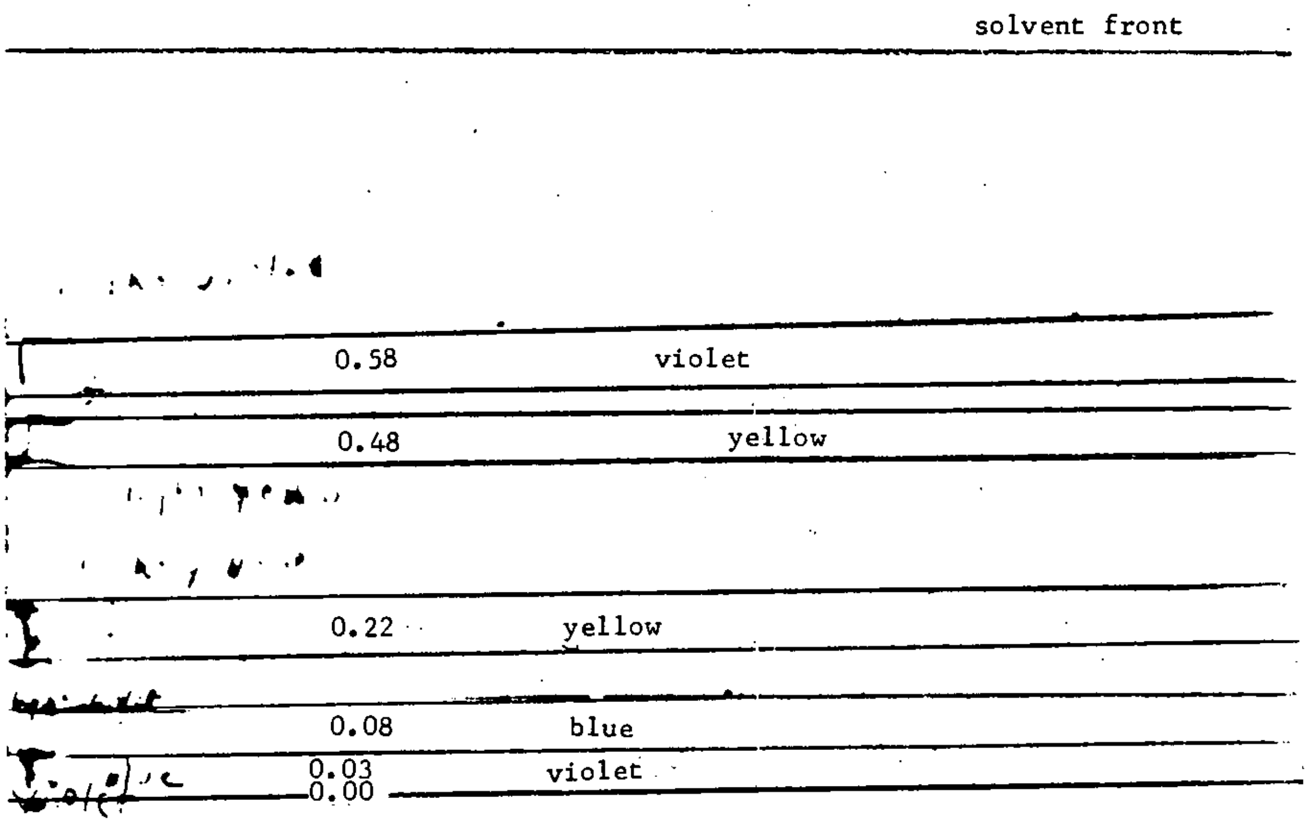


Figure A-10 - TLC of Sample SS-111-2

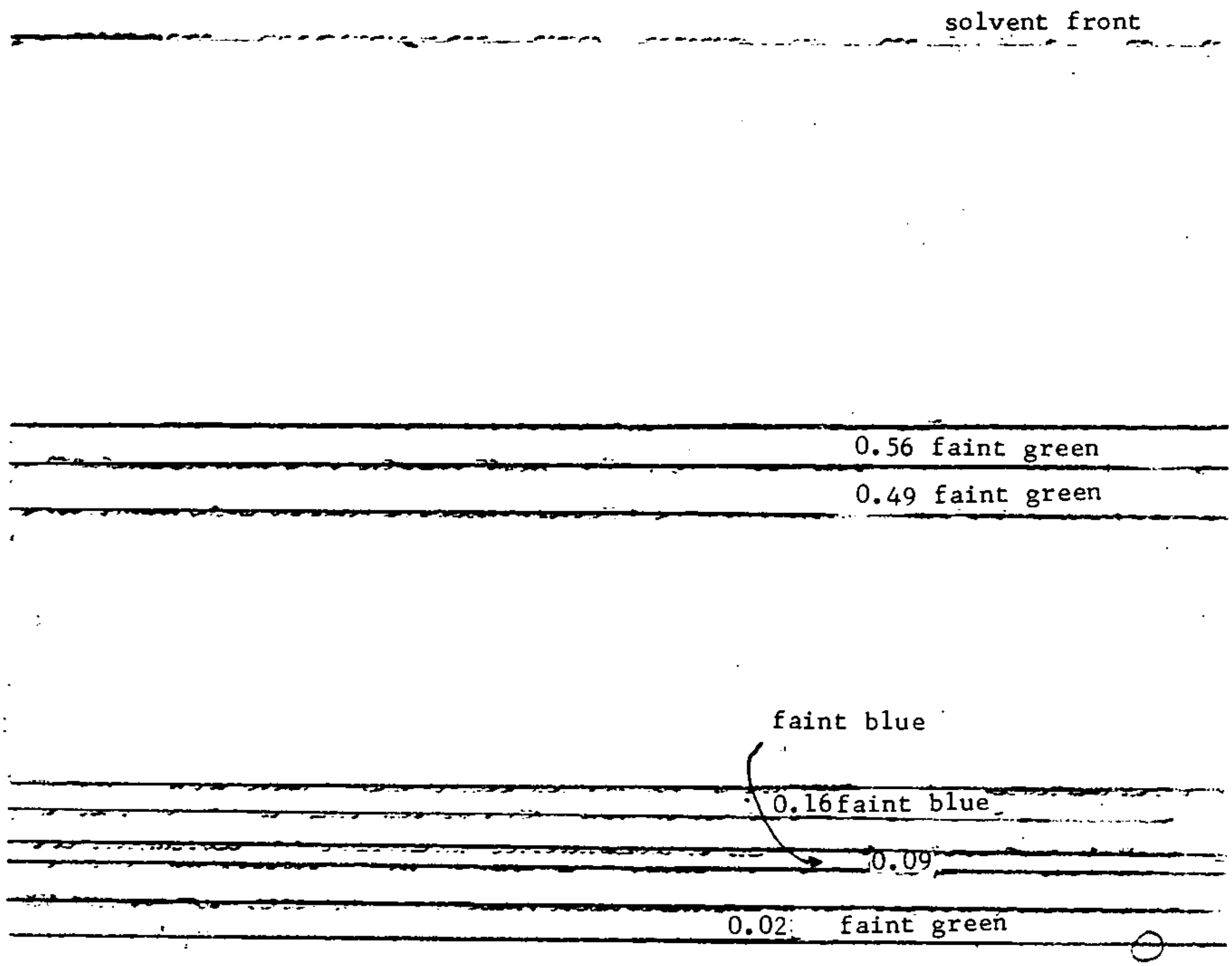


Figure A-11 - TLC of Sample SS-111-3

APPENDIX B

GAS CHROMATOGRAMS OF SELECTED EXTRACTS

The figures of this section show the gas chromatographic traces for five selected soil extracts.

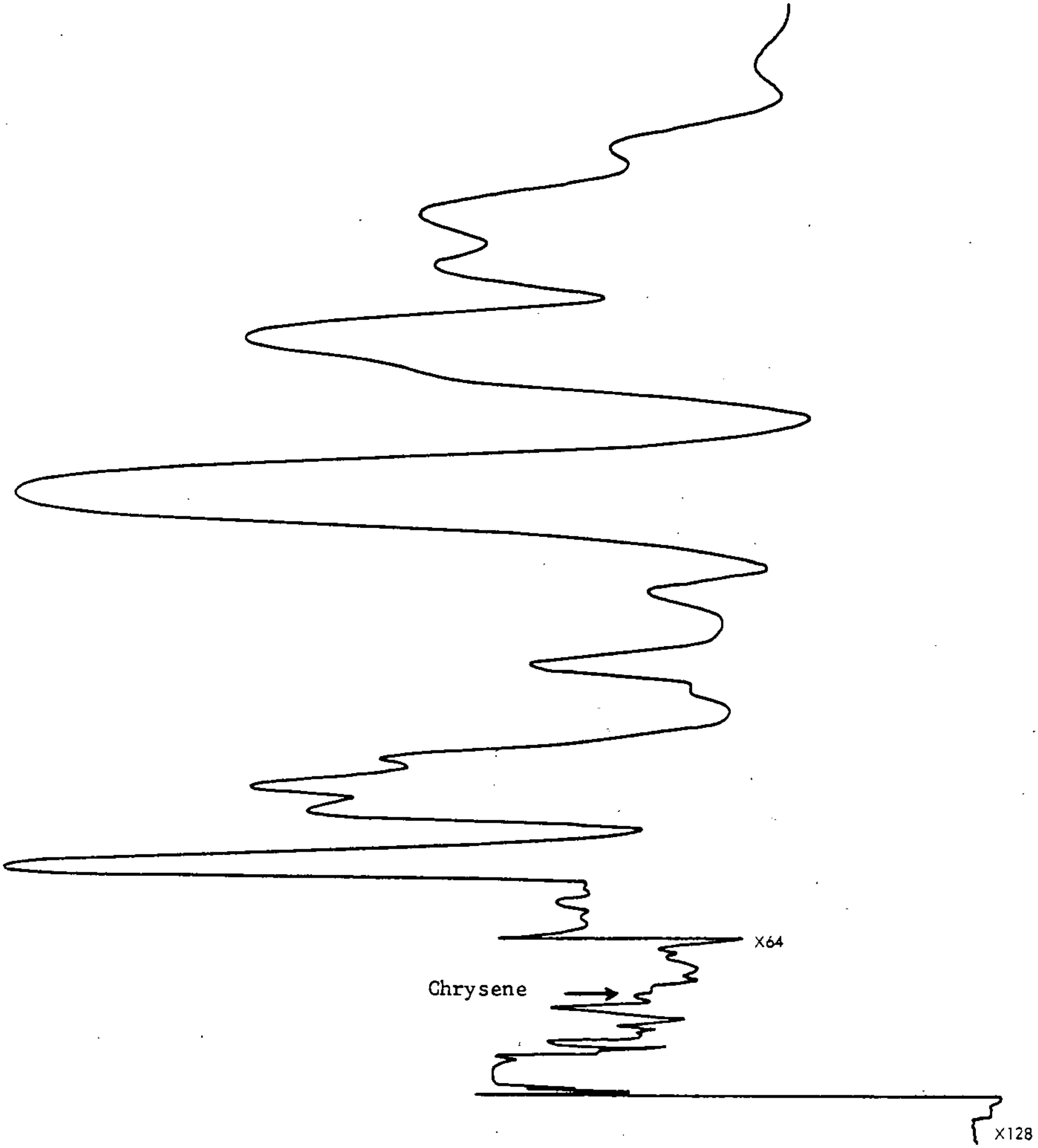


Figure B-1 - GC of Sample SS-105-1

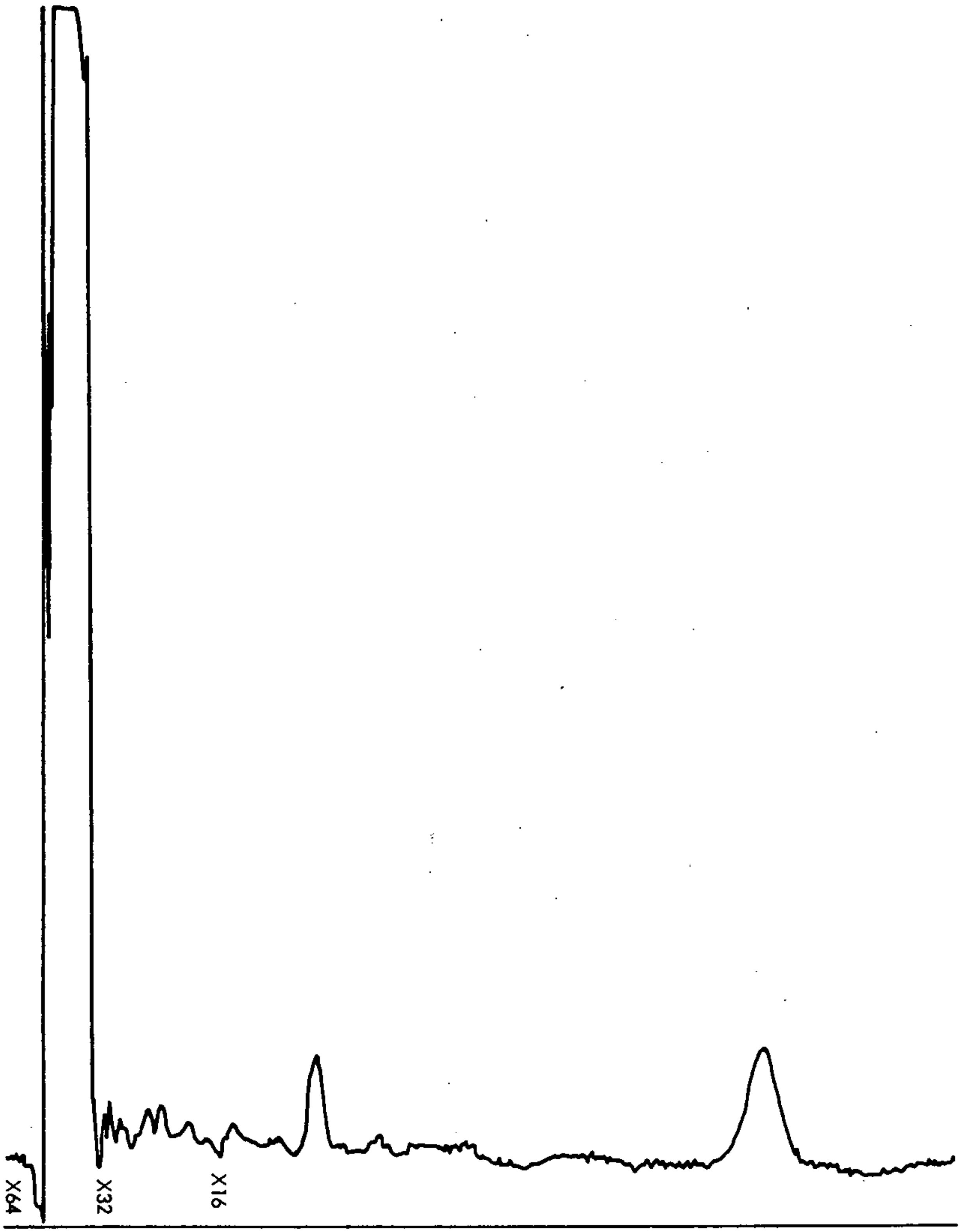


Figure B-2 - GC of Sample SS-105-2

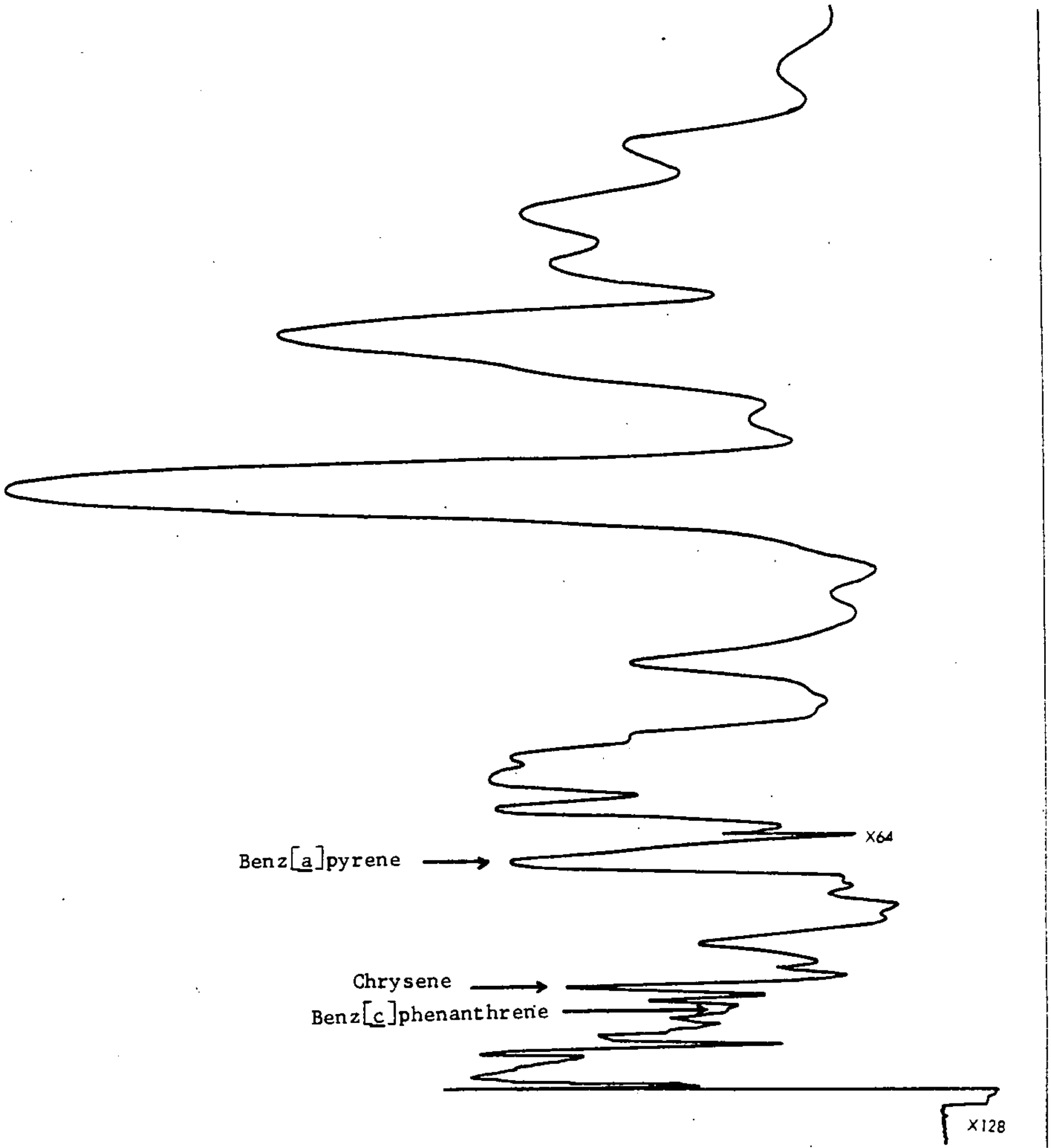


Figure B-3 - GC of Sample SS-109A-2

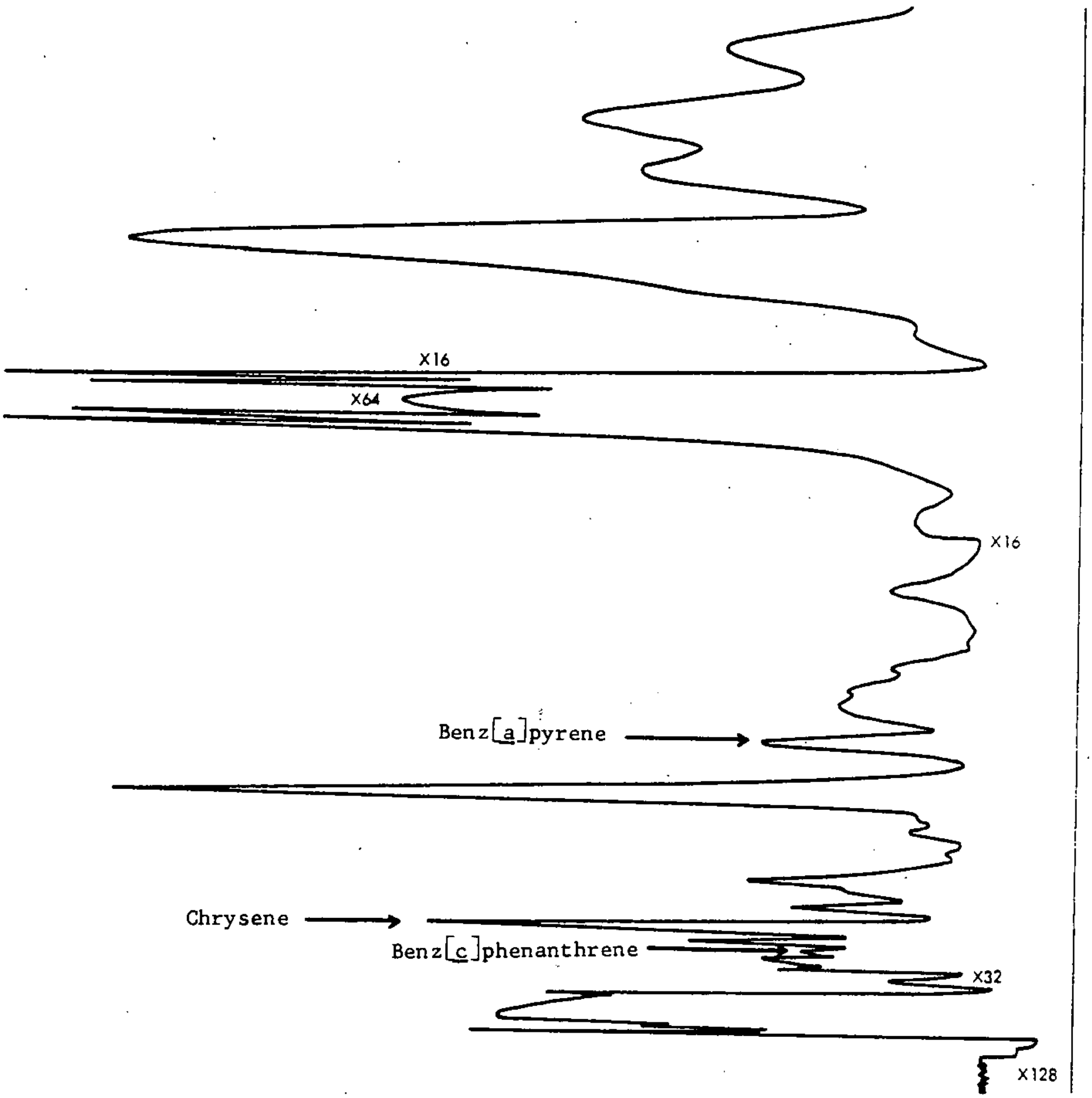


Figure B-4 - GC of Sample SS-109B-1

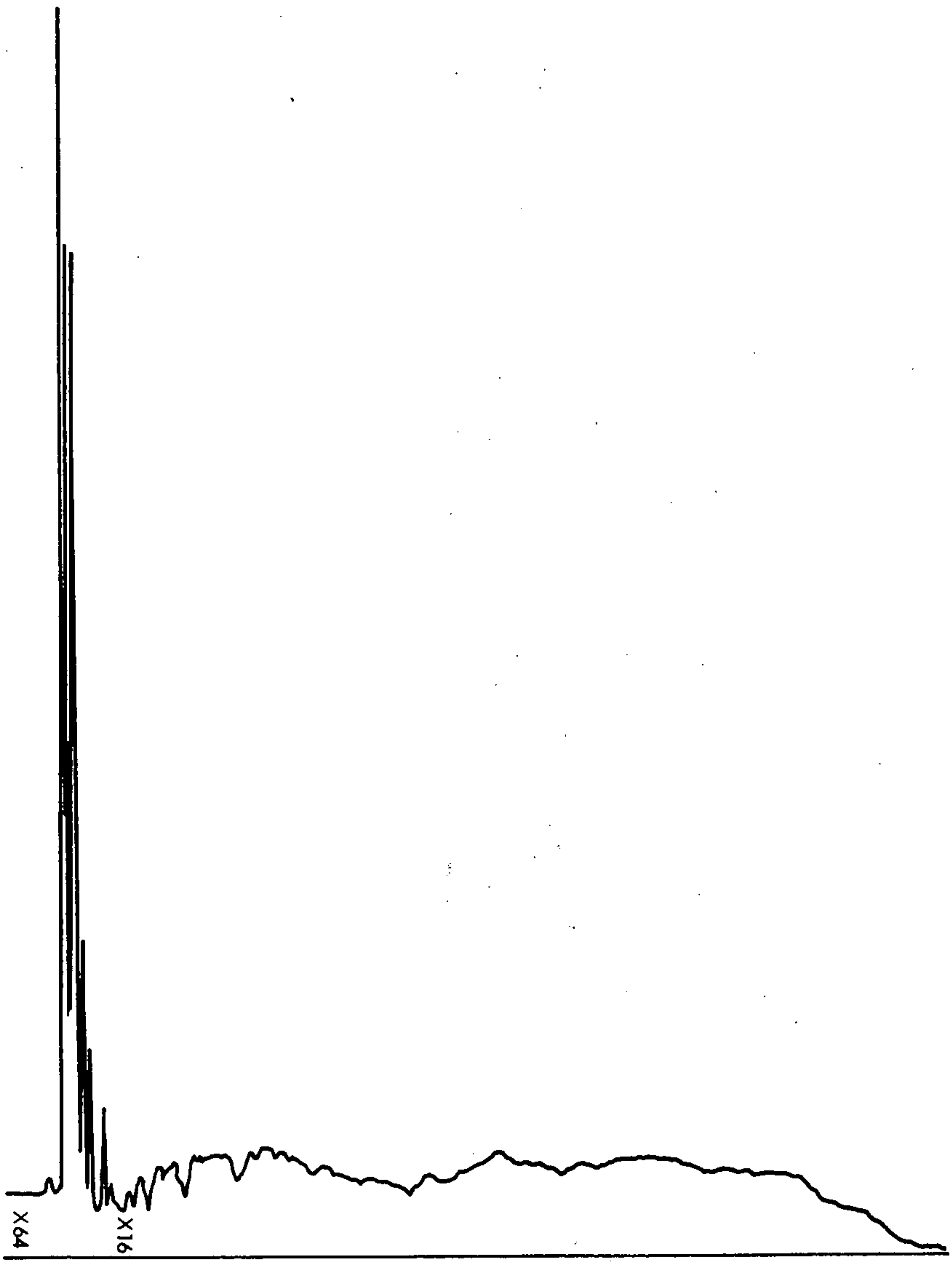


Figure B-5 - GC of Sample SS-111-2

APPENDIX D

DETAILED DISCUSSION OF PHENOLIC AND BENZENE EXTRACTABLE DATA

APPENDIX D

DETAILED DISCUSSION OF PHENOLIC AND BENZENE EXTRACTABLE DATA

The purpose of this Appendix is to discuss, in more detail, the phenolic and benzene extractable data from the soil samples collected during Phase I. The locations of the various soil borings in relation to the coal-tar distillation and wood preserving facilities formerly on the site are also discussed and are illustrated on the figure included in this Appendix.

Borings 1 and 2 were located in the northern portion of the site in areas used to store treated wood products. With the exception of a trace of phenolic material measured in a sample collected at a depth of 15 feet, phenolics were not detected in soil samples from Boring 1 above a depth of 55 feet. Phenolic concentrations in three of the last four soil samples collected between the depth of 55 feet and bedrock at a depth of 75 feet, averaged approximately .8 mg/kg. Benzene extractable material on the other hand was detected in soil samples collected throughout the soil column with the sample at the 10 foot depth exhibiting a benzene extractable concentration of 2,200 mg/kg and samples between the 10 foot depth and bedrock exhibiting concentrations between the detection limit and 200 mg/kg. Judging from the soil samples, phenolic material in Boring 2 is more generally distributed throughout the soil column than phenolic material in Boring 1. In Boring 2, phenolics were between 1 mg/kg and 1.3 mg/kg in the first three soil samples collected between the ground surface and a depth of 15 feet and averaged approximately .5 mg/kg in samples collected between the 20 foot depth and the termination of the boring at 45 feet. Benzene extractable material was between 3,000 and 3,500 mg/kg in the two samples collected above the 10 foot depth and dropped to near 100 mg/kg in samples collected below the 10 foot depth.

Borings 3 and 4 were placed near the former autoclave where creosote was forced into the wood under pressure. Phenolic concentrations in Boring 3 were between 3 mg/kg and 1.5 mg/kg in samples collected in the upper 7-1/2 feet and dropped to levels just above the detection limit below the 7-1/2 foot depth with the exception of the sample collected at the 30 foot depth, which contained a phenolic concentration of 1.2 mg/kg. Benzene extractable material was as high as 16,400 mg/kg in samples collected from the fill and peat soils in the top 10 feet of Boring 3 and a black creosote-like substance exhibiting a strong creosote-like odor was present in the samples collected in the top 10 feet of this boring. Benzene extractable material in soil samples collected below the peat were generally between 100 mg/kg and 200 mg/kg. Phenolics and benzene extractable materials were high in samples collected from the fill and peat soils in the upper 12-1/2 feet of Boring 4 with visible creosote-like substances noted in the samples. Phenolics were typically over 15 mg/kg with one value over 200 mg/kg and benzene extractable material was typically over 15,000 mg/kg, with one value over 188,000 mg/kg. Phenolic concentrations between 1 mg/kg and 3 mg/kg were measured in samples between depths of 15 and 30 feet in Boring 4. Below the glacial till stratum at the 40 foot depth, the soil samples indicated that the phenolic concentrations decreased to levels below .5 mg/kg and benzene extractable levels were near or below the detection level to bedrock.

Borings 5 and 6 were located near former buried pipelines and storage tanks on the property. Phenolic material was at or below the detection limit in soil samples collected below the 15 foot depth in Boring 5. Benzene extractable material was less than 200 mg/kg below the 15 foot depth. Samples collected in the upper 15 feet of Boring 5 indicated saturation with visible creosote-like wastes. Phenolic levels ranged from 6.6 mg/kg to 1.2 mg/kg and benzene extractable material ranged from 9,300 mg/kg to 1,100 mg/kg with both parameters decreasing with depth. Soil samples indicated that the phenolic material is more generally distributed throughout the soil column represented by Boring 6 than in the soil column represented by Boring 5. A phenolic level of 9.1 mg/kg and a benzene extractable level of 13,100 mg/kg were measured at the 5 foot depth of Boring 6. Phenolic levels varied from 1 mg/kg at the 15 foot depth to near the detection limit of .2 mg/kg at the 35 foot depth. Near a depth of 40 feet, the phenolic concentrations increased to 1.4 mg/kg just above a thin sandy-clay till layer. Phenolic concentrations near 1 mg/kg were measured in samples collected above and below till layers at depths of 22 feet and 55 feet and the phenolic concentration increased to 5.1 mg/kg at the 70 foot depth near bedrock. The concentration of benzene extractable material was less than 100 mg/kg in samples collected between the

10 foot and 45 foot depth, but increased to over 1,000 mg/kg in two of the last three samples collected in this boring.

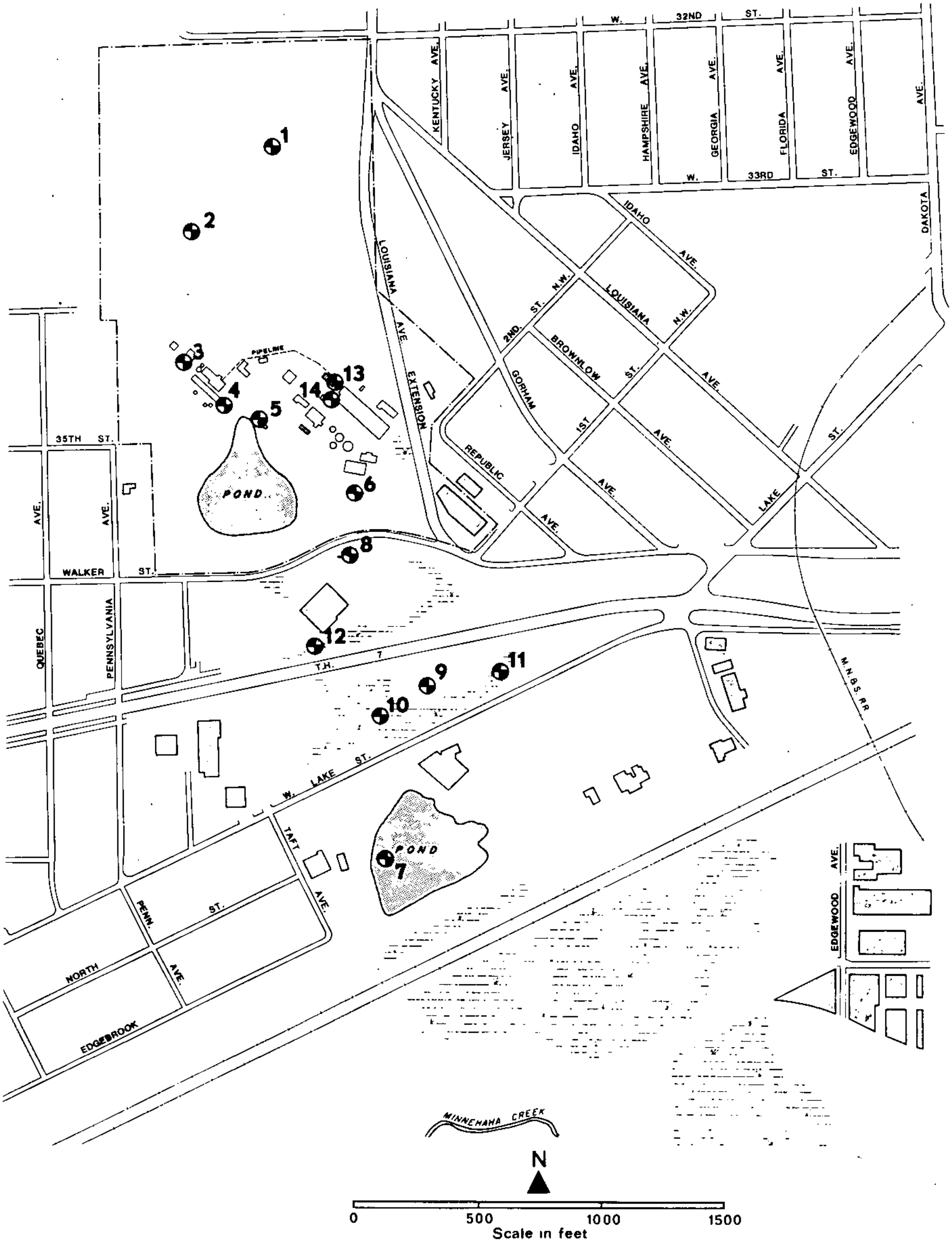
Boring 13 and 14 were located immediately northwest of the former refinery used to separate creosote from coal-tar. Samples collected from Boring 13 indicated high phenolic and slighty elevated benzene extractable concentrations between the 2 and 5 foot depths. Phenolic concentrations were less than 1 mg/kg between the 5 foot depth and the base of the boring at a depth of 57 feet. The concentration of benzene extractable material was between 290 mg/kg and 130 mg/kg in samples collected between the 5 foot and 23 foot depth and levels dropped to near or below the detection limit in samples collected below the 23 foot depth. Phenolic concentrations between .9 mg/kg and 3.9 mg/kg were present in five of six samples collected from the top 15 feet of Boring 14, and the benzene extractable concentration was 19,500 mg/kg at the 5 foot depth. Phenolics and benzene extractable material decreased to near the detection level in samples collected at the 15 and 20 foot depths; however, the phenolic concentration increased to 2.2 mg/kg and the benzene extractable concentration increased to 2,600 mg/kg in a coarse sand layer at a depth of 25 feet. No glacial till was found in this boring above a depth of 40 feet; however, it is hypothesized that a thin till layer likely exists, possibly between the 25 foot and 30 foot depths. Below 30 feet, phenolic concentrations in the soil samples were near the detection limit as were the benzene extractable concentrations, with the exception of the benzene extractable concentration of 425 mg/kg measured in a sample collected above a fine silty sand stratum near the 40 foot depth.

The remaining soil borings were located off the site of the former coal-tar distillation and wood preserving facility. Borings 8 and 12 were placed in lowland areas south of Walker Street and north of T.H. 7. Natural drainage from the site was through the general area sampled by these borings. Samples from Boring 8 indicated visible contamination between the surface and the 25 foot depth. Phenolic and benzene extractable levels in samples collected from the top 10 feet exceeded 22 mg/kg and 23,600 mg/kg, respectively. Samples collected from the lower portions of the peat soils at a depth of 12 feet and from a gray-green sand clay layer immediately beneath the peat indicated substantially reduced phenolic and benzene extractable levels.

However, both the phenolics and benzene extractable material increased in the samples collected at the 15 and 27 foot depth below the gray-green sandy clay. Phenolic concentrations varied between .8 mg/kg and 1.5 mg/kg in samples collected between the 30 and 40 foot depths. At a depth of 45 feet below the surface, in a medium sand stratum beneath a red sandy till stratum, a phenolic concentration of 2.9 mg/kg was measured. Phenolic concentrations then decreased in samples collected at the 50 and 55 foot depths; however, phenolic concentrations increased again to approximately 2.5 mg/kg in samples collected from the bottom 15 feet of the glacial till encountered in Boring 8. Samples from Boring 8 exhibited a layering of phenolic and benzene extractable concentrations with high values reported in granular soils immediately above the till layers and lower concentrations in the soils beneath the till layers. The chemical concentration layering is also characteristic of borings placed between T.H. 7 and Lake Street. Visible contamination was indicated in the samples collected from the top 10 feet of Boring 12. The phenolic and benzene extractable concentrations were much higher, however, in the peat soils in the upper 5 feet of this boring than in the fine sands and gravels at the 10 foot depth. Below the 15 foot depth, phenolic material was at or near the detection level and no detectable phenolic material was found above the glacial till stratum at a depth of 50 feet or in the till immediately above the bedrock. Benzene extractable material was detectable, but less than 300 mg/kg below the 15 foot depth. The two borings located between Walker Street and T.H. 7 indicate different phenolic characteristics, especially in the granular soils above the till layers.

Borings 9, 10 and 11 were placed south of T.H. 7 and north of Lake Street. Drainage from the site entered this lowland area and reportedly only rarely overflowed south of Lake Street. Boring 10 was the most westerly and Boring 11 was the most easterly of these three borings. These borings will be discussed from west to east beginning with Boring 10. Samples collected at Boring 10 indicated visible contamination from the surface to a depth of 30 feet. Phenolic and benzene extractable concentrations were very high in samples from the peat soils. Phenolics remained high in the silty clay soil beneath the peat; however, benzene extractable material decreased significantly below the peat. Below the sitly clay stratum, remained above 4 mg/kg to a depth of 30 feet. Below the 35 foot depth, the concentration of benzene extractable material in the soil samples decreased to 175 mg/kg and phenolic concentrations decreased to .7 mg/kg. Phenolic concentrations between 2 mg/kg and 3 mg/kg were present immediately above the red till layer encountered at a depth of 40 feet. Phenolic concentrations were detectable, but less than 1 mg/kg above and within the second till layer 55 to 65 feet below the ground surface. Boring 9 exhibited high phenolic and benzene extractable materials in peat samples collected in the top 4 feet. Benzene extractable material remained high in the sample collected at a depth of 5 feet, but the phenolic concentration unexplainedly dropped to below the detection limit. The phenolic and benzene extractable material decreased below levels measured in the sample at a depth of 4 feet, in the peat samples collected between the depths of 10 and 20 feet. Phenolic and benzene extractable materials both increased in the sample collected in the gray-green clay layer that forms the base of the peat soils. Benzene extractable material and phenolics than decreased sharply between the 30 foot depth and the 45 foot depth. In a sample collected just above a gray sandy clay layer at the 48 foot depth, however, the phenolic concentration increased to 2.2 mg/kg, while the benzene extractable materials increased to 1,740 mg/kg. Phenolic concentrations increased to 7.8 mg/kg in the till layer, while the benzene extractable concentration decreased to 170 mg/kg. Below the gray sandy clay till layer, benzene extractable material and phenolic concentrations were measurable but less than 200 mg/kg and 1 mg/kg, respectively. High phenolic and benzene extractable concentrations were also measured in the peat soil samples in the top 10 feet of Boring 11. Samples collected below the 10 foot depth indicated that phenolic concentrations decreased to less than 1 mg/kg, with the exception of just above a sandy clay layer at the 30 foot depth, where a phenolic concentration slightly exceeding 1 mg/kg was measured. Below the 45 foot depth, phenolic concentrations were below the detection limit in the soil samples. Below the 15 foot depth, benzene extractable material was near the detection limit in the soil samples.

Boring 7 was taken in the storm water storage pond south of Lake Street and north of the Chicago & Northwestern Railroad during pond construction. The top of Boring 7 was at Elevation 878, which is approximately 8 feet below the natural ground level in this area. Soil samples from Boring 7 indicated benzene extractable levels at or near the detection limit throughout the entire boring. The only detectable phenol concentration was a concentration of .4 mg/kg measured in a gray sandy clay till layer at the 30 foot depth.



LOCATION OF PHASE I SOIL BORINGS